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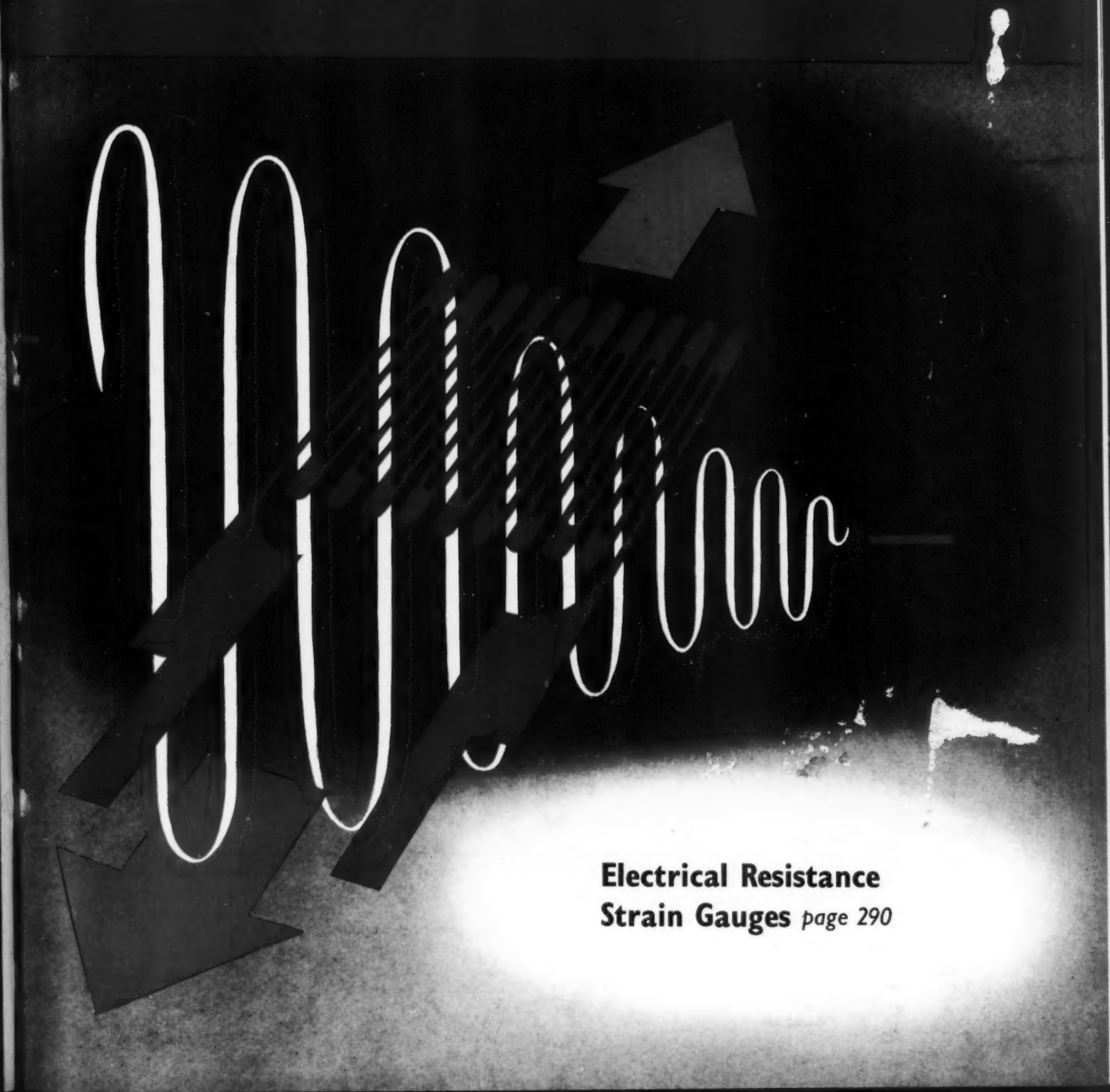
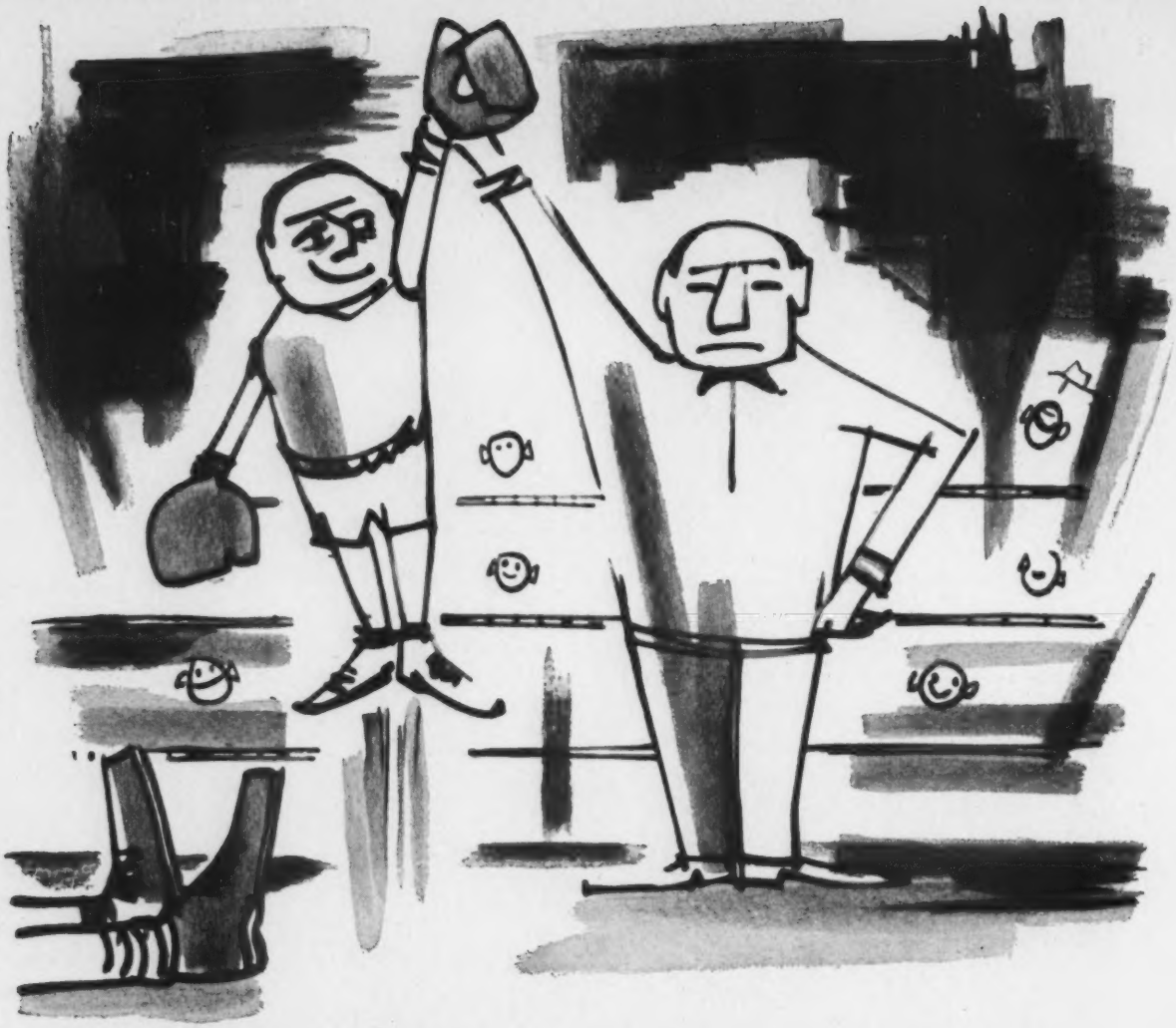


Electrical Resistance Strain Gauges *page 290*

EMD 6287 for further information



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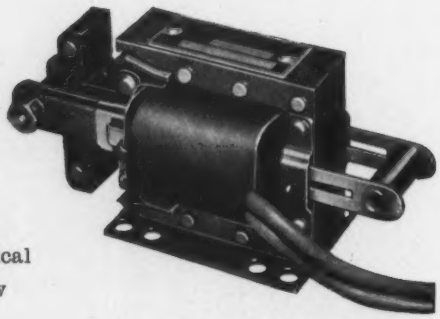

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Engineering Materials and Design

★ *The Magazine for Engineering Designers*

A HEYWOOD PUBLICATION

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CAOUTCHOUC A BASSES TEMPERATURES

par D. A. Smith page 278

L'auteur examine la nature physique du durcissement des caoutchoucs à basses températures et montre comment il est possible, en utilisant des polymères de base convenables, soigneusement composés, d'éviter ce phénomène.

FORMULES POUR CYLINDRES EPAIS

par A. Ormerod page 283

Cet article traite principalement des méthodes permettant d'évaluer les tensions qui se manifestent dans les cylindres à parois épaisses soumis à des pressions nternes et externes.

EXTENSOMETRES POUR RESISTANCES ELECTRIQUES

par J. Edwards page 290

L'emploi d'extensomètres pour déterminer les contraintes dans les structures statiques et dynamiques permet à l'ingénieur d'obtenir des renseignements essentiels. L'article définit les principes en jeu et indique divers types d'extensomètres dans le commerce.

CONVERTISSEUR DE FREQUENCE A INDUCTION

par P. B. Greenwood page 302

L'auteur décrit le principe de son fonctionnement, le choix du nombre de pôles, le réglage de la tension, la définition de la puissance et le travail à phase unique. Il examine également les techniques de construction et les applications.

Kurzreferate

NIEDRIGTEMPERATURGUMMI

von D. A. Smith Seite 278

Der Verfasser bespricht die physikalischen Eigenschaften der Kälteerhärtung von Gummi und weist darauf hin, wie dies durch die richtige Kompaundierung geeigneter Grundpolymerisate beseitigt werden kann.

KONSTRUKTIONSFORMELN FÜR DICKE ZYLINDER

von A. Ormerod Seite 283

Der Artikel bespricht Mittel zur Bestimmung der Spannungen in dickwandigen Zylindern unter inneren und äusseren Drücken.

ELEKTRISCHE WIDERSTANDS-SPANNUNGSMESSER

von J. Edwards Seite 290

Der Einsatz von Widerstands-Spannungsmessern zur Bestimmung von Spannungen in statischen und dynamischen Strukturen liefert dem Konstrukteur notwendige Daten. Der Artikel bespricht die Grundsätze und zeigt die verschiedenen Typen von Geräten an.

INDUKTIONS-FREQUENZWANDLER

von P. B. Greenwood Seite 302

Der Autor bespricht die Betriebsgrundsätze, Wahl der Polzahl, Spannungsregelung, Energienormung und Einphasenarbeit, sowie auch Methoden der Konstruktion und des Einsatzes.

Резюме

ОХЛАЖДЕНИЕ РЕЗИНЫ

Д. А. Смит стр. 278

Автор статьи обсуждает физические свойства затвердения резины при низкой температуре и показывает, как этого явления можно избежать выбором подходящих основных полимеров, смешанных надлежащим образом.

ФОРМУЛЫ КОНСТРУКЦИЙ ТОЛСТО-СТЕННЫХ ЦИЛИНДРОВ

А. Ормрод стр. 283

Статья рассматривает главным образом методы, при помощи которых можно уточнить степень напряжения в цилиндрах с толстыми стенками, подвергающихся наружному и внутреннему давлению.

ТЕНЗОМЕТРЫ ЭЛЕКТРИЧЕСКОГО СОПРОТИВЛЕНИЯ

Ж. Эдвардс стр. 290

Применение тензометров сопротивления для определения степени напряжения как в статических так и в динамических структурах, дает конструктору необходимую информацию. Статья устанавливает связанные с этим правила и перечисляет имеющиеся типы тензометров.

ТРАНСФОРМАТОР ЧАСТОТЫ ИНДУКЦИОННОГО ТИПА

П. Б. Гринвуд стр. 302

В статье описывается принцип действия, выбор количества полюсов, регулирование вольтажа, нормирование мощи и одно-фазного действия. Обсуждается также техника конструкции и различные применения.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Thermionic Conversion Device

SCIENTISTS OF U.S. GENERAL ELECTRIC are testing a thermionic conversion device that may greatly increase the overall efficiency of nuclear power stations. This device, called a plasma diode, is a high temperature thermionic converter using caesium gas and a uranium-bearing cathode. These diodes could be built into nuclear fuel elements, where the fission of the uranium in the cathode would provide the high temperatures—in the region of 2,480 deg C.—needed for efficient direct conversion. An electrical lead from the fuel element would draw off the electricity. Heat rejected by the device would be converted into electricity by the standard thermodynamic cycle. Single-cell devices able to generate several watts are now undergoing tests in a special fuel capsule in a test reactor.

Although thermionic conversion devices capable of producing approximately 20 W. per sq. cm. of cathode area have been demonstrated, much more development will be necessary before they will be suitable for general application. However, recent design advances indicate that an advanced plasma diode should be ready to be tested in a prototype nuclear power plant within five years.

Oxidation-proof Graphite

IN THE SEARCH for new materials to withstand high temperatures, metals are now receiving competition from the non-metals developed by Boeing Airplane Co., of Washington, U.S.A. One of the most important of the latter is graphite, a form of elemental carbon which is used in many applications where heat resistance is needed. However, until recently its use has been limited because of its tendency to oxidise at elevated temperatures.

In many materials, resistance to oxidation is due to the fact that, when these are exposed to oxidising environments at high temperature, a protective coating forms spontaneously from the oxidation of the base materials. If damaged, the coatings are self healing, immediately reforming from the exposed materials. To produce oxidation resistance in graphite, refractory borides, silicides, nitrides or carbides (all of which form refractory oxides upon oxidation) are added, together with small amounts of bonding agents. A typical system consists of graphite, molybdenum disilicide and titanium diboride. Though a wide range of formulations is available, the optimum graphite content is in the range of 40 to 60 weight per cent, corresponding to 60 to 80 volume per cent.

In the fabrication of specimens the components are first mixed, then milled to produce a uniform mix which will pass through a 200 mesh screen. After adding a liquid binder and pressing at 5,000 to 15,000 p.s.i. the material is plastic and fairly strong. During the firing operation the binder carbonises and then graphitises.

The composites form a smooth adherent yellowish-brown layer, about 0.001 in. thick, when heated in air for 3 hr. at 1,200 deg. C. As temperature and exposure time increase, the protective layer increases slightly in thickness and becomes more refractory. The colour becomes darker with increasing temperature.

Since the coating is irregular, it clings to the "core" more easily, the irregularities having an anchoring effect. The surface appears to consist entirely of oxides, with the composition varying through the coating, and containing some ceramics which are partially or completely unoxidised. These new materials are stronger than commercial grade graphite at both room temperature and 1,650 deg. C. Room temperature moduli of rupture for the composite materials are about double those obtained from commercial graphite, being as high as 10,000 p.s.i. The bodies containing a higher graphite content (about 70 volume per cent) gain strength with increasing temperature. On the other hand, when the graphite content is lower, the composites lose strength with increasing temperature, but remain stronger than graphite.

The compressive strength of the graphite composites at room temperature are about double that of commercial graphite. Tensile properties have not yet been evaluated, but it appears that the values will also be about double those of graphite.

Because of the ceramic additives, both the density and coefficient of thermal expansion of the composites are higher than those of commercial graphite. The thermal expansion of the composites varies linearly with graphite content. Although the expansions are higher, the composites retain good thermal shock resistance because of the graphite matrix. Typically, the materials withstand five cycles of heating to 1,430 deg. C. in air, followed by quenching in water, without failure.

To test the oxidation resistance, one composition in the systesm $MoSi_2$-TiB_2-graphite was heated under oxidising conditions for varying times, to 1,200 and 1,430 deg. C. At 1,200 deg. C., coating thickness increased from 0.54 mils at 1 hr. to 1.65 mils. at 8 hr. At 1,430 deg. C. the thickness changed from 3.72 mils at 1 hr. to 14.82 mils at 8 hr. The coatings were hard and adherent, and did not crack or spall upon cooling.

When the specimens were inserted directly into the heated furnace, the coating formed was thinner than when the specimen was placed in a cold furnace slowly brought up to the same temperature. The specimens showed no dimensional changes after 3 hr. at 1,430 deg. C. However, when such bars were heated for longer periods the corners became rounded.

This experimental work is in its infancy, and much remains to be done in the determination of physical properties and optimum compositions. Whatever is found in the future, however, it appears certain that a graphite-ceramic composite has been devised which is very useful.

Developments in Welding

THE SPRING MEETING of the Institute of Welding is to be held in London, from April 25 to 28. Ten papers are to be presented at three technical sessions on the mornings of April 26, 27 and 28.

At the first session the Institute will discuss recent developments in contact type electrodes, the use of gas mixtures in gas shielded bare wire welding, and automatic tungsten arc welding of heat exchangers.

The second session is to be devoted to metal spraying and brazing. One paper will deal with automatic controls of mechanised metal spraying equipment, and another will describe an adhesion test for aluminium spray-coatings and other metallised surfaces carried out at the National Gas Turbine Establishment.

The last meeting will be concerned with stud welding, a new German process called foil seam welding, and some work undertaken at the British Welding Research Association on the inert gas shielded metal arc welding of thick copper without preheat.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN

SUPERSONIC WIND TUNNEL

A new 4 ft. x 3 ft. closed-circuit wind tunnel at the R.A.E. (Bedford) was recently opened by the Minister of Aviation. G.E.C. supplied the whole working section leg and here screens which smooth the airflow are seen being placed in position.

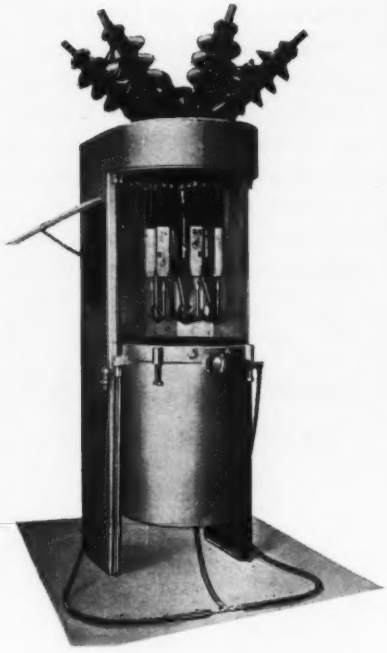
NEW GAS TURBINE

The Austin 250 h.p. gas turbine shown for the first time at the A.S.E.E. Exhibition is specially suitable for stand-by generators and emergency fire pumps. All the components are assembled by hand and here the first stage nozzle rings are being dropped into place.

GLASS FIBRE DEPOSITOR

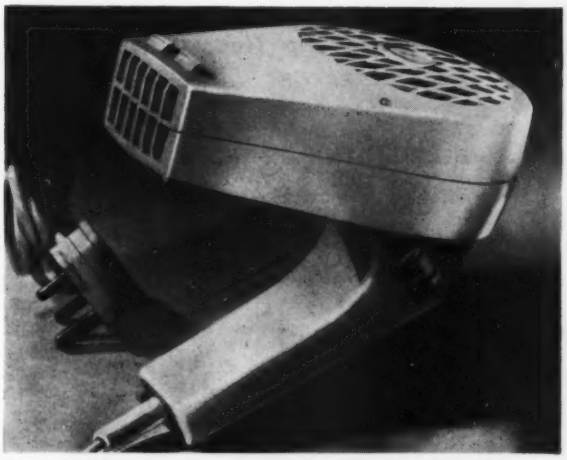
With increasing production the depositor technique is finding new applications in glass fibre fabrication. At Orma Plastics Ltd. a Criss depositor using Turners Duraglass Chrome Complex Rove is used to lay up a glass reinforced facia panel for the A.E.C. Routemaster bus.

COLD SCOUT
The Westland P531 Scout helicopter recently underwent cold chamber trials down to minus 35 deg C. The Blackburn Nimbus engine is reported to have started first time at this temperature.



ANGLED BUSHINGS
The new 33 kV Reyrolle out-door oil-brake circuit-breaker uses angled bushings to achieve a compact design. It makes full use of modern materials including an epoxy encapsulated aluminium foil closing coil and a glass fibre laminate plunger bar.

LUXURY LIFE HAIR DRYER
Bridges' sleek new hair dryer (right) available in pink, lilac and ivory features an interesting new design enabling the dryer to be used in the hand, stood on a table or hung on a wall. There is no need for an extra stand.



EXPANDED P.V.C. INSULATION
Plasticell, supplied by Microcell Ltd., is a closed cell expanded P.V.C. having good thermal insulating properties. This photograph shows 20 cubic foot containers being assembled with interlayers of this insulation for a cold storage plant of T. Wall & Sons Ltd.

What saves a cylinder from losing its head?

How does a cog-wheel know when to turn, what makes a casting lasting? What stops a gear from gritting its teeth, what saves a sump from fasting?

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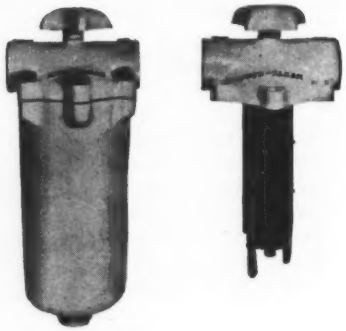

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A range of filters is also available for varying applications and flows up to 150,000 gallons per hour.

New Electroluminescent Discoveries

NEW DISCOVERIES have brought the industrial and equipment lighting of the future—electroluminescence—one step nearer reality. This lighting illuminates whole metal sheets by the use of phosphorous, which lights up when an electric current is passed through it. No filaments or elements are needed.

Dr. Peter W. Ranby (chief chemist at the Lighting Laboratories of Thorn Electrical Industries Ltd.) and his research group have developed a method that increases the brilliance of the plates more than three times. This, says Dr. Ranby, gives Britain the European leadership in the electroluminescent field, and an equal footing with the U.S.A. Hitherto the brilliance at 240 v. and 50 c/s was 1 foot-lambert. The new developments have raised this to 4 foot-lamberts at 2,000 c/s. The increased brilliance is due to general improvements in processing, and the use of new enamels.

As far as it is known, this is the only British company developing the "ceramic on metal" type of electroluminescent product with a lamp built upon a steel sheet which forms the back electrode. The phosphorous is embodied in a vitreous enamel, fired at high temperatures. The lamp is completed with a conducting transparent layer of tin oxide to form the second electrode, and a protective clear overglaze.

It is claimed that ceramic lamps are more robust and versatile than the "organic on glass" lamps, which consist of a glass sheet on which a transparent conducting film of tin oxide is deposited, followed by a phosphorescent layer in an organic resin binder. The capacitor is completed by a second electrode of evaporated metal and the assembly sealed with paraffin wax to exclude moisture. This type of lamp is supplied as cabin signs for many aircraft, including Comets and Caravelles.

These lamps are suitable for aircraft instruments, car instrument panels and radio tuning dials—luminous clock faces and map readers are already in production. Plans for the future include the use of electroluminescent road signs for the new motor ways. Once installed, running costs will be negligible.

Glass for Aircraft

OPTICAL GLASS, which is the highest quality glass manufactured, and used primarily for lenses and prisms, is taking the place of plate glass in the windows of Britain's modern aircraft. The faster-than-sound speeds of today's military and civil planes calls for the highest degree of clear vision for the pilot. Optical glass can provide this, for it is a clear white glass and one which undergoes the most rigorous inspection tests during manufacture.

An optical window for an aircraft does not leave the manufacturer if there is so much as a pin-point flaw either in the glass or on the surface. For such a spot is what a pilot first sees when he is approached by another plane on the same flight level, and at speeds of around 600 m.p.h. a head-on collision can occur within seconds.

Three glass works, many miles apart, are involved in the manufacture of these windows. The glass is actually made at the Chance-Pilkington Optical Works, at St. Asaph, in North Wales, where previously optical glass had only been made in widths of up to 12 in. Glass for aircraft windows needs to be more than three times as wide, and it took nearly twelve months concentrated development, and the installation of new plant, to achieve this. Before leaving St. Asaph the glass is inspected in its rough cast form.

The grinding and polishing, and marking of the glass by template, is carried out by Pilkington Brothers, of St. Helens, Lancashire. The use of a shadow-graph (a penetrating light which throws the shadows of flaws onto a white backcloth) guides the cutter to the best and most economical way of cutting the glass into window shapes. Before leaving the factory it is finally surface polished.

The third stage, that of toughening and laminating, is carried out by Triplex Safety Glass at their Birmingham works. Here it is examined on at least four more occasions, to test its ability to withstand pressurisation and the structural load of the aircraft and its flatness of surface, and to search for minute flaws which can only be detected by means of special optical tests.

After these tests, and after toughening, the glass is laminated, i.e. made into a sandwich of between two and six sheets of glass with metal inserts between each sheet. Special optical work is carried out on bomb aimers, camera windows and high accuracy windscreens, and bending is part of the preliminary work for curved screens.

Heated windows have a deposit of gold film and bus bars inserted into the sandwich, and terminal blocks are affixed to the corners of the glass or on the outer window structure. These windows undergo special electrical and refrigeration tests before final inspection.

Russian Exhibition in London

THE SOVIET TRADE AND INDUSTRY EXHIBITION, organised by agreement between the U.S.S.R. Chamber of Commerce and the Association of British Chambers of Commerce, will open at Earls Court on July 7. The British firm Industrial and Trade Fairs Ltd. is helping in the arrangement of the exhibition, which is the biggest of its kind to be held in Britain. It will occupy an area of approximately 270,000 sq. ft.

Visitors will see replicas of the atomic power stations which are being built in the Urals and elsewhere, and will be shown a model of the Saratov hydro-electric power station—the first in the world to be built almost completely of prefabricated reinforced concrete parts.

There will be a replica of the latest 2000 cu. metre blast furnaces, with their mechanised installations, and the method of application of natural gas in blast furnaces—a method developed and used on an industrial scale for the first time in the Soviet Union—will also be displayed.

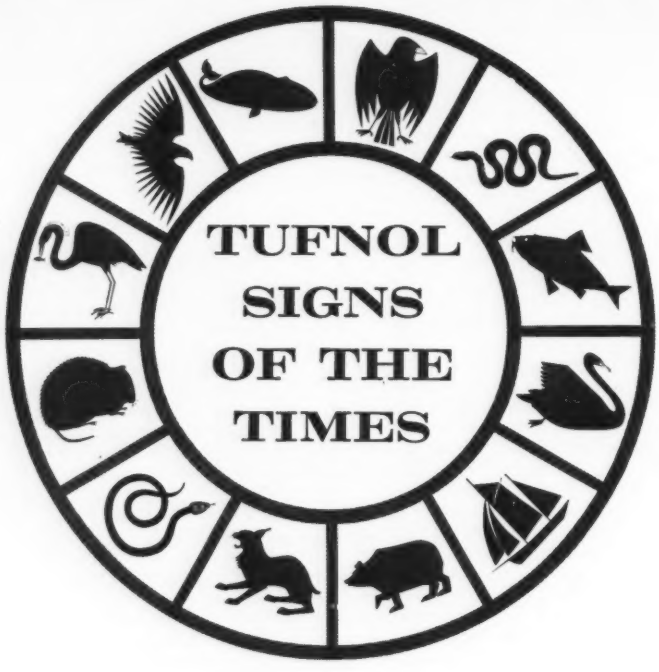
Most of the machinery, instruments and installations will be shown in operation, a running commentary being given in English by automatic "interpreters," each with up to 400 earphones.

A big display will be presented by the Soviet automobile industry, featuring lorries, cars, buses, ambulances, motorcycles and motorscooters.

The latest Soviet TV sets, refrigerators and washing machines will also be exhibited.

An extensive and varied display will show visitors Russia's achievements in the various scientific fields, particularly those of atomic energy, space flights, electronics and optics. Machines, welding equipment, safety appliances and electronic devices will demonstrate the work being done by industrial research establishments in the Soviet Union.

A Vanguard main pilot's window, after assembly and autoclaving, being edge sealed.



Kite—sign of Tufnol

Those people born under the sign of the Kite ascend in ever increasing circles until they reach the top of their profession. Kite men become chief purchasing officers, chief engineers, chief draughtsmen and chief designers. Kite men are perfectionists with eyes like hawks. They hunt for a material that combines the properties of many materials—a material that is light yet strong and hardwearing, resistant to corrosion and a good electrical insulator. They also expect this ideal material to resist deterioration in storage, to machine easily with ordinary tools, and to be available in sheets, tubes, rods, angles, and channels. Many Kite men have already spotted this ideal material—"KITE" brand Tufnol. They have also discovered that Tufnol is available in eleven other brands, each with pre-determined properties.

All brands of Tufnol are laminated plastics; each formulated to satisfy specific requirements. If your birthday falls between January 1st and December 31st, this could be your lucky week—the week you discovered Tufnol.

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F2

Properties of Gases and Liquids

DATA ON THE PHYSICAL PROPERTIES of fluids are so scattered throughout numerous journals and reports that the industrial user may not be aware of their existence. In addition they are recorded in different units, and so often need conversion to a convenient form. The National Engineering Laboratory (East Kilbride, Glasgow) has been collecting data from all over the world, and offers a service to industry in answering specific enquiries; specialist advice can be given on the selection of the most reliable results from contradictory sources.

Data are available on thermodynamic properties (such as enthalpy, compressibility and specific heat) and transport properties (such as viscosity and thermal conductivity). Values of the physical properties of about twenty of the commoner fluids, for example air, ammonia and argon, are indexed at N.E.L. in standard units, and their accuracy has been assessed. Data can also be provided on many other organic and inorganic fluids, including refrigerants.

Most enquiries can be answered immediately from existing information on the particular fluid involved; if the required experimental data are not available, it may be possible to determine them from other properties of the fluid, from the same properties of other fluids, or from theoretical considerations. Information can also be given on methods of extrapolation and interpolation of experimental data, and on the range over which this may be done safely.

An electronic digital computer is available at N.E.L. for calculating physical properties; it has already been used in the preparation of the British draft of the new international skeleton table for steam, covering temperatures up to 800 deg. C. and pressures up to 1000 atmospheres.

Requests for information on thermal conductivity, viscosity or thermodynamic properties of a specific fluid should include details of the temperature and pressure range at which data on a particular property are required. No charge is made for the service unless a substantial amount of work is necessary. Critical surveys of existing data on the physical properties of several fluids have been produced, with tables of recommended values.

Advanced Heat Transfer

A COURSE OF TEN LECTURES on refrigeration heat and mass transfer is to be given in the National College Building, Southwark Bridge Road, S.E.1, commencing on April 11. The course will be suitable for those engaged in the design, specification and manufacture of refrigeration and air conditioning equipment, and should be of interest to refrigeration engineers, air conditioning engineers and those engaged in industry on process cooling. Engineers and scientists with a general interest in heat and mass transfer will also profit from the lectures. Students should be graduates in science or engineering, or possess other suitable qualifications and experience. It is essential that students should already have at least an elementary knowledge of heat transfer.

THE JUNE ISSUE

of *Engineering Materials and Design* will include the following main features:

Glass in Modern Engineering

Showing how glass has become an indispensable factor in industry.

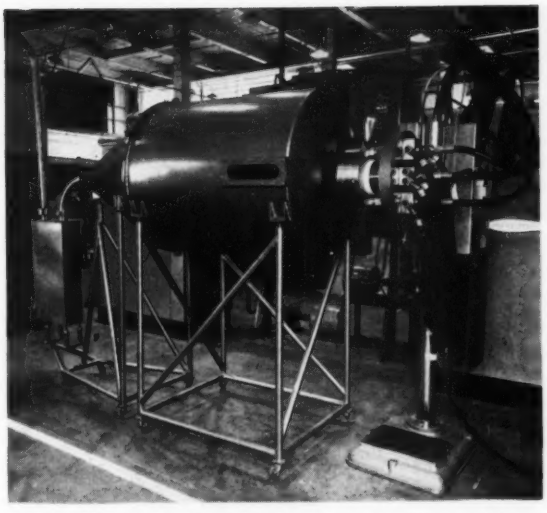
Freewheeling Devices

Survey of the ranges available from the principal British manufacturers and suppliers.

Research into Design Activity

Describing research carried out by the University of Cambridge with a view to guiding technical education.

The Gyroscope and its Uses



Convair's modified air plasmajet (right centre), assembled with a test chamber.

Taming the Plasmajet

A MODIFIED VERSION of the air plasmajet in current operation at the Convair Division of General Dynamics Corp., San Diego, California, has been proved to be eminently practical for many high temperature applications, due to its ability to control intense heat.

Briefly, the air plasmajet is a device which heats a gaseous stream with an electric arc. Because it can produce temperatures higher than those existing near the surface of the sun, it has been extremely useful in spraying high-temperature metal and refractory powders. But it has been unsuitable for many applications because its heat output could not be accurately regulated and measured. For instance, the range of heat transfer rates or heat flux required for performance testing materials for thermal protection systems is from about 540 to 5,500 deg. C. These temperatures must be produced within tolerances of ± 3 deg. C. under predetermined flow conditions at atmospheric and reduced pressures if accurate test data are to be obtained. In addition, it is desirable to work with specimens which are somewhat larger than those which can be tested with conventional air plasmajet equipment.

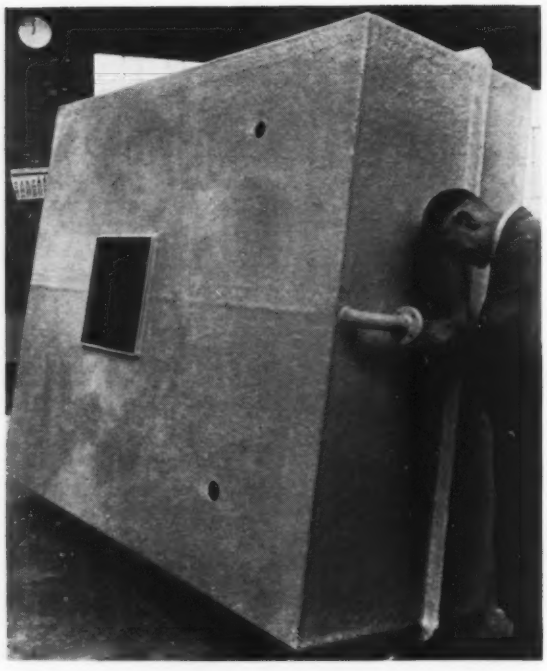
Taming the plasmajet mainly involved the insertion of an aerodynamic nozzle between a standard plasmajet unit and a test chamber. This nozzle has several water cooled segments, any or all of which may be used to reduce the temperature of gas leaving the plasmajet and to impart a desired velocity to the heated gas.

Other modifications consisted of adding adjustable electrodes to the plasmajet to permit the efficient usage of voltage and amperage for different heating operations, and special provisions which make it possible to employ nitrogen as a stabilising gas.

To ensure the accurate production or reproduction of specified temperatures, several highly sophisticated calorimeters have been developed for the modified plasmajet. One such device is capable of supplying a signal for the continuous control of critical operational variables by indicating changes in calibrated air or water used for cooling purposes.

Ball Bearings in Watches

THE BRITISH MANUFACTURED BEARINGS CO. LTD., of Crawley, Sussex, are carrying out research and development work in connection with sub-miniature ball bearings in the form of pivots. These minute precision bearings can be used as substitutes for jewels in wrist-watches. Ball-bearings of this type have already been used to replace jewels in scientific instruments. It is expected that this revolutionary departure will have a far-reaching effect on the mechanical efficiency of watches and their durability.



Tank with integral piping. The p.v.c. layer provides corrosion resistance, while the reinforced polyester covering gives the required strength. (Courtesy: Plastics Constructions Ltd.)

Reinforced P.V.C. Sheet Laminate

ENGINEERS HAVE LONG APPRECIATED the advantages of the chemical inertness of p.v.c. sheeting, but have often been unable to employ the material because of its lack of strength at elevated temperatures. Reinforced polyester and similar resins, while possessing adequate strength, are not sufficiently inert to serve as process vessels.

This situation has now been transformed by the introduction of a new polyester resin developed by Artrite Resins Ltd., 44-46 Kingsway, London, W.C.2. This resin enables a backing of glass fibre-reinforced resin of great strength to be intimately laminated to one side of a p.v.c. sheet, leaving the other side of the sheet free to contain the materials to be processed. Resin and reinforcement are applied directly to the p.v.c. by the conventional wet lay-up technique, but when the resin sets the laminate forms a homogeneous strong material.

This new patented method of plastics construction has already been employed with great success to produce piping, tanks, ducts, hoppers and similar structural parts for chemical plant. Most brands of both polyvinyl chloride and polyvinylidene chloride sheeting can be used, provided the plasticiser content is not too great. Any thickness of sheeting can be employed, the choice being governed mainly by the techniques used to fabricate the sheet. Hot welding is most commonly used, although vacuum forming is also suitable.

The most significant difference between the laminating process and conventional reinforced plastics production is the fact that no moulds are needed. Only simple supporting frames, or the cheapest plaster and wooden formers are now required, since the resin never comes into contact with the supports. The careful preparation of mould surfaces, the use of release agents and the application of polyester gelcoating resin is eliminated, the necessary surface finish being already available on the p.v.c. sheeting.

The method used to produce the composite laminate is very similar to that employed for wet lay-up on a conventional mould, but the surface of the sheeting to be reinforced must first be thoroughly sanded and, immediately before laying up, the surface must be cleaned to remove all dust and grease.

Provided the laminate is correctly formed, the strength of the bond is much greater than that of either layer of material. Tests of lap joints usually result in failure of the p.v.c. or, if the reinforced plastics layer is very thin, in a breakdown between resin and fibres. The mechanical strength of the laminate as a whole is said to be far superior to plain p.v.c.

There is little doubt that the combination of a relatively thin vinyl sheet, strengthened by a backing layer of glass fibre-reinforced polyester resin, opens up a number of possibilities for more economic plant construction. The applications of the process may well spread rapidly with growing appreciation of the advantages of combining the inertness of p.v.c. with the structural rigidity and strength of reinforced poylester resin.

New Nickel Steel

A NEW 18 per cent nickel alloy steel, said to have unmatched toughness at the highest strength levels of traditional alloy steels, has been discovered and developed by scientists of The International Nickel Co. Inc. This discovery paves the way for a new family of high-strength steels with advanced engineering design possibilities for civilian and defence applications involving exceptionally high pressure and stress.

The new alloy is the only known material which has the ability to achieve a yield strength in excess of 250,000 p.s.i. while maintaining a nil ductility temperature below −62 deg C. Another outstanding characteristic is its excellent notched tensile strength, which is said to exceed 400,000 p.s.i. (measured under the most severe test conditions with a notch radius of 0.0005 in.). Tests have shown that this new alloy possesses a remarkable resistance to delayed cracking when exposed to a corrosive atmosphere in a stressed condition.

The new steel develops its high strength while maintaining unmatched ductility and toughness by means of a remarkably simple heat-treatment involving age-hardening of martensite. This treatment has been given the abbreviated description of "mar-aging." With proper finishing temperature off the mill, followed by air cooling to room temperature, the treatment consists merely of holding for about 3 hr. at 480 deg. C. and air cooling. Solution annealing at 820 deg. C. prior to mar-aging is optional. Quenching is not required, and full properties can be developed in heavy sections with no distortion problems.

The new alloy has a nominal composition of 18 nickel, 7 cobalt, 5 molybdenum, less than 0.5 titanium and a maximum of 0.05 per cent carbon. Higher and lower tensile strength can be obtained by modification of this basic composition. There are indications that high strength levels of up to 500,000 p.s.i. or even higher may be achieved in this type of steel. A 10-ton commercial heat has been produced by air melting in an arc furnace, and ingots as large as 23 x 42 in. from this heat have been rolled into plate on conventional steel mill equipment. Eighteen per cent nickel steel can be readily produced in all commercial shapes.

Unusually low work-hardening tendencies permit extensive cold forming and shaping with ease. The machining characteristics of the steel are excellent, both as rolled and even as fully hardened.

The 18 per cent nickel steel can be readily welded by either manual or automatic methods. Sound crack-free welds are said to be achieved, even on material in the fully heat-treated condition, without preheating. Post-weld mar-aging restores the softened heat-affected zone of the parent plate to full strength, and establishes in the weld metal properties closely approaching those of the base plate.

A patent application covering this new nickel steel has been filed with the U.S. Patent Office.

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ENCOURAGEMENT WITH INTEREST

SINCE the war there has been a considerable growth in the size of personnel departments. In addition to their obvious functions of selecting the right kind of employee, acting as go-between in disputes, keeping records, etc., additional duties often include the organisation of sports and social club activities, and endeavouring to maintain a cheerful atmosphere in the works.

For the many, engaged upon possibly dull repetitive work with little to offer in the way of career prospects, such activity can be important. But for the young designer, development engineer or craft apprentice there must be something more. He may find social activity within the works boring, and at the end of a day's work be glad to get away from it all. The frustration of coming day after day into a drawing office and toiling at a highly specialised job can be great, particularly when, as often happens in the larger type of organisation, he gets no recognition or praise for his efforts. In some large concerns splendid layouts and schemes are often examined by executives who have hardly spoken to the man whose brainwork they represent. The chief draughtsman, often an unpopular and harassed executive, disliked by both his subordinates and superiors, reigns supreme over a frustrated group of younger men who study the "Situations Vacant" columns each day as they await the tea trolley! It is not necessarily pecuniary reward that they seek—it is very often interest, an outlet for their ideas and scope for self-improvement in the technical sense.

If he is to get on in his career, the young engineer must widen his horizon. Although he may belong to the local branch of his institution, the lectures may not often have a close enough bearing on his actual work to warrant a visit. If he works in an outlying area, travel to a nearby town may be expensive and tiring after a long day.

An admirable scheme recently introduced by Spembly Ltd., of Chatham, a firm of design development and consulting engineers, provides for meetings, to be held initially at monthly intervals, at which speakers deliver papers in a formal manner, although every attempt is made to keep the atmosphere informal. Selected papers will be printed for record or submitted for publication in suitable journals and relative professional institutes. Although in the main the subjects will be of a technical nature, there will be scope for non-technical departments to offer subjects explaining their activities and occasionally, or as appropriate, visitors will be invited as guests of the company.

At the first meeting, held on February 28, a paper entitled "Considerations in the Design of Plastic Nozzle Forming Machines for Macleans Ltd." was submitted by Mr. F. W. Shorter, chief designer. Further meetings will include the following subjects: "Echo Area Measurements, their Significance and Techniques," and "Design and Construction of Large Graphitising Furnaces."

The scheme seems to us to be of particular interest in that it will teach the engineers concerned to become articulate. The accurate verbal presentation of technical matter is a most useful accomplishment, and tends to improve thinking in both speaker and audience. Even good engineers tend to be poor speakers and very often, in our experience, bad writers.

We are reminded of what the little girl said: "Mummy, how can I know what I think till I hear what I say?"

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TOO MANY "WHIFFLEBIRDS"

IN spite of the astonishing pace at which the number of creative achievements are increasing in all industries, there is a continual demand for more men, particularly engineering designers, having creative ability. At the same time there is a general outcry that more should be done to train and educate creative men. In many countries research is being carried out to find out just what it is that characterises a creative individual, with the object of determining how to select and train suitable candidates for creative jobs. A study of these scientific investigations is rewarding and sometimes amusing (incidentally, a sense of humour has been listed by one United States authority as an essential part of a creative character!).

Many people think that creative ability is inborn, and that therefore it has to be discovered rather than taught. However, there is a growing belief that creativity can be deliberate, and that it can be developed in most if not all engineers. Dr. M. C. De Malherbe (of the department of mechanical engineering, Imperial College), writing in the February 1961 issue of *Technology*, states: "A university graduate should be educated and not trained; he should not be conditioned to produce a predetermined response to a given stimulus. He should be capable of reviewing a problem critically and of solving it in an uninhibited manner, relying not merely on previous experience but using instead originality and the logic of the scientific approach. It should be possible to develop, to some extent, these capabilities in the student during his university studies with the help of a well-run design course."

Other authorities have expressed the view that creativity is largely the result of a particular attitude of mind, which can be fostered by appropriate incentives. Unfortunately, what most investigators seem to overlook is that, although our education system for teaching creative design may be out of date, a far bigger problem is the obstructive attitude so often met in industry, where creativity is usually interpreted as inability to co-operate. Too many firms are unable to distinguish between criticism and disloyalty. It should not be considered disrespectful to question authority or expert opinion, because the very essence of creativity is dissatisfaction and an urge to do a better job. Unfortunately, this attitude brings the creative individual into direct conflict with his superiors, and very often shows him up in bad light against his colleagues who usually toe the line obediently with a "yes sir, no sir" policy, content to follow the band.

Nothing blocks new ideas in design more effectively than the habitual use of old methods, and nothing upsets the solution of problems more completely than frustration. All the fuss that is being made about educating young men so that they will become creative scientists and engineers will be of no avail if, when they emerge into industry, their spirit is crushed by managements encumbered by bad habits acquired over generations.

According to Harold R. Buhl, who has just written a book called *Creative Engineering Design* (published by the Iowa State University Press), there exists in the U.S.A. a strange beast called a "Whifflebird", which flies backwards because it prefers to see where it has been rather than where it is going. Unfortunately, this creature is something of a pest in Britain too; in fact, we strongly suspect that his ancestors originated in a large engineering company over here! Although non-progressive management is often subject to ridicule in this way, humorous treatment should not disguise the serious consequences that this attitude is having on British prestige and trade. We recommend all senior managers and directors to subject themselves to a period of self-examination by asking themselves: "Do you help with the solutions, or are you merely part of the problem?"

The Editor

LOW-TEMPERATURE RUBBERS

The author discusses the physical nature of low-temperature stiffening of rubbers, and indicates how this phenomenon may be obviated by the choice of suitable base polymers, properly compounded

by D. A. SMITH, M.Sc., A.R.I.C., A.I.R.I., A.N.C.R.T. *

ALL rubbers remain serviceable only over a limited temperature range. In a previous article[1] the upper limits of the range were discussed, and it was pointed out that the heat-resistant limitations of our present-day elastomers are associated with chemical modifications such as oxidative scission of structural units, which may take place rapidly at elevated temperatures. These chemical changes are generally irreversible; that is to say, a rubber which has been degraded by exposure at too high a temperature for too long a time will not regain its elastic properties when its temperature is reduced.

In contrast, the principal changes which occur in rubbers exposed at low temperatures are physical in nature, and the lost properties may usually be restored by warming. However, while this may be satisfactory for certain idle or static components exposed intermittently at low temperature, the majority of designers will want their rubbers to retain elasticity under cold conditions, and it is the purpose of this article to discuss the physical nature of low-temperature stiffening and to indicate how it may be overcome by the choice of suitable base polymers, properly compounded.

Physical Explanation of Stiffening

The constitution of every rubber, whether natural or synthetic, consists of long chain molecules constructed of many hundreds of repeating units, which serve as "chain links".[2] The links are reasonably flexible, and so the many long chains which go to make up a macroscopic piece of rubber are coiled and twisted at random, besides being intimately entangled one with the other. Every chain is joined to every other chain at a few points along its length by chemical "cross-links" inserted by the process of vulcanisation. These cross-links serve to prevent slippage of chains over one another when the material is stressed (the phenomenon of "creep" or "cold flow" observed with typical thermoplastics), the whole piece of rubber being, ideally, one giant three-dimensional chemical molecule in the form of a "network structure". It is the deformation and recovery of this network which controls the reversible high elastic deformability characteristic of rubbers. Any long chain molecule constructed of flexible links will be subject to "Brownian motion", and will take up a random configuration unless restrained by mechanical forces acting at the ends of the chain. When the rubber network is completely relaxed, the thermodynamic entropy of the system is a maximum (i.e. a disordered state) but, as it is stretched, the ends of the chains are effectively "pulled apart", work is done on the system, and a degree of orientation is imparted to the structure which leads to a reduction in entropy. Conversely, when the stress is released, the network elements will once again revert to the random configuration (maximum entropy, minimum internal energy), the process being termed "high elastic recovery". The effect of high temperatures on the Brownian motion of the chain links will be to increase this motion but, as the temperature falls, the movement will become more and more sluggish and the chains will take longer and longer to adjust themselves to a given state of stress. This is easily demonstrated by the application of an impulse stress to a rubber such as butyl, which shows high internal damping. In a favourite lecture demonstration, a butyl and a natural rubber ball are bounced on the bench at room temperature, the former rebounding hardly at all. Both balls are then heated in a beaker of boiling water and the experiment repeated, when the butyl ball bounces as high as its natural rubber counterpart. The explanation, of course, is that the higher temperature has enabled the butyl chain segments to move faster, and so cope with the deformation caused by the impulse stress in the characteristic fashion of the high elastic network. It follows that a rubber will only show high elastic behaviour when the segmental relaxation time, T_m, is much less than the frequency of the applied stress. Many rubbers show good elastic behaviour under the British Standard 903 conditions of stress/strain testing (20 in./min. elongation rate) but are defective in resilience and other dynamic tests involving higher rates of strain (see Fig. 1).[3]

In addition to this internal damping effect, reducing the environmental temperature may cause stiffening of the rubber and loss of elasticity due to crystallisation before the polymer reaches its "glass transition temperature". Below this temperature, the flexibility of the chain links is negligible and the material behaves as a typical amorphous solid (e.g. a glass) (see Fig. 2).[4] For raw natural rubber, this "glass transition" occurs at about −70 deg. C.; vulcanisation may raise this temperature up to say −55 deg. C. The

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presence of polar groupings in the constitution of the chain links will raise the glass transition temperature, and it is unfortunate that those rubbers which are prized for oil seals and gaskets owe their resistance to swelling by hydrocarbon fluids to the presence of just those groupings which are responsible for deteriorating the low-temperature properties (see Table 1). A compromise must therefore be sought between oil resistance (high polar group content) and good low temperature flexibility (low polar content), and it is for this reason that manufacturers of nitrile rubber (NBR), a typical base polymer for oil seals, market a number of grades with different acrylonitrile (polar) content.[5] Further improvement can be effected by compounding methods, which are discussed later in this article.

The second factor contributing to stiffening is partial crystallisation of the polymer. Crystallisation involves the lining up into parallel bundles not of whole molecules, as happens in the crystallisation of monomeric substances, but rather of portions of different polymer chains (see Fig. 3).[2] Orientation takes place by random thermal motion and, at low temperatures, the energy of the segments is not sufficient to break the strong interchain cohesional forces which are sufficient to bind the bundle together. If the rubber is now warmed, the thermal energy imparted to the chains will enable their convulsions to break them loose from the bundle, and the crystallites will be destroyed. Once again,

Table 1. Glass transition temperatures for various "raw" (i.e. uncompounded) polymers

		°C.
Non-polar	Polyisobutene	−74
	Natural rubber	−73
Polar	Butadiene-acrylonitrile rubber (65/35)	−30
	Nylon	+47
	Polyvinyl chloride	+75

Table 2. Glass transition temperature related to copolymer composition

		°C.
Butadiene-styrene copolymer	(67/33)	−70
" " "	(50/50)	−54
" " "	(33/67)	−33
" " "	(9/91)	+50
Polystyrene	(0/100)	+83

the polar polymers (e.g. neoprene) show high interchain cohesion, and may be more susceptible to crystallisation than the less polar polymers. A complicating factor is the presence of bulky side groups which effectively prevent chain alignment; thus SBR, which is more polar than NR, nevertheless shows much less tendency to crystallise, because of packing difficulties. Again, the method of polymerisation may confer structural regularity, as in the case of Ziegler polyethylene, which is much more crystalline than the older high-pressure types. Partial crystallisation of rubbers can also be induced at almost any temperature by the application of high tensile stresses, which physically "pull out" the chain segments into alignment. The crystallites formed in this way contribute to the very high tensile[6] and tear strengths obtained with these materials in contrast to non-crystallising rubbers. As a result, rubbers under strain crystallise at higher temperatures than when in the unstrained state (see Figs. 4 and 5).[7]

The maximum rate of crystallisation usually occurs at some temperature a few degrees above the glass transition and so, under the less severe conditions of low-temperature service, crystallisation is likely to be a more frequently encountered phenomenon than embrittlement. Crystalline frozen rubber differs from rubber in the glassy state in that

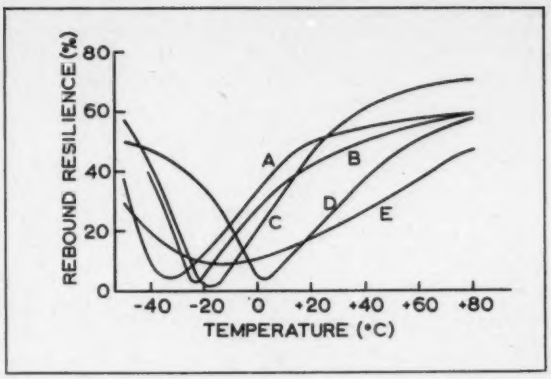

Fig. 1. Rebound resilience as a function of temperature for: *A* NR; *B* SBR; *C* neoprene; *D* NBR (35/65); and *E* butyl.

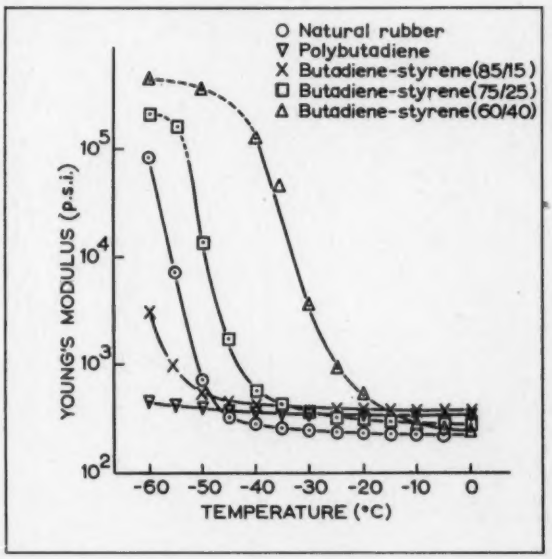

Fig. 2. Young's modulus versus temperature for various rubber vulcanisates (deflection measured 10 sec. after application of load). (After J. W. Liska.)

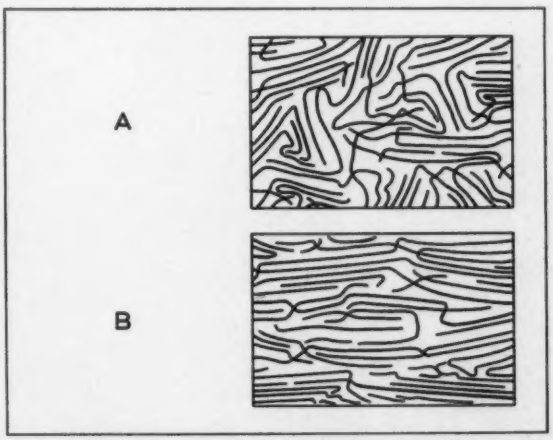

Fig. 3. Diagram representing the molecular structure of crystalline rubber—*A* unstretched, and *B* stretched, before crystallising. (The parallel bundles represent crystallites.) (After Treloar.)

Fig. 7. Resilience of elastomer blends: (A) NR; (B) NBR (35:65); and (C) 50:50 blend.

Fig. 4. Incipient crystallisation temperature of a silicone rubber as a function of extension ratio (α).

Fig. 8. Different resilience/temperature relationships of four commercial polyurethane rubbers: (A) Chemigum SL; (B) Adiprene C; (C) Prescollan; and (D) Genthane S.

Fig. 5. Crystalline fraction in silicone rubber as a function of temperature and of extension ratio (α). (From X-ray data.)

Fig. 9. Effect of temperature on hardness of a typical "extreme low temperature" silicone rubber vulcanisate.

Fig. 6. Relationship between cold flex temperature and plasticiser nature and concentration (for polyvinyl chloride).

the former retains a certain degree of flexibility or rubber-like elasticity combined with great toughness or resistance to fracture, although there is a tendency for the rubber to "set" in the form imposed by external stresses. In contrast, rubber below the glass transition temperature is extremely hard, inelastic and brittle. Some elastomers respond to chemical treatments which reduce their tendency to crystallise. Various treatments have been proposed: Cunneen and Swift[8] use butadiene-sulphone to reduce the maximum rate of crystallisation of NR several hundredfold at −26 deg. C., while Ritter[9] recommends the addition of about 2 per cent of thiolbenzoic acid. Chloroprene polymers (neoprenes) are notorious for their crystallinity, vulcanised gaskets and seals based on the older grades showing "after-hardening" even at temperatures above freezing point, but crystallisation-resistant grades have been introduced containing structural irregularities in the form of copolymerised styrene.[10]

Among the outstanding low-temperature rubbers are the silicone elastomers. Dimethyl silicone rubber has a glass transition temperature of −123 deg. C. (cf. NR at −73 deg. C.), and crystallises rapidly between −50 and −60 deg. C. For practical purposes, these rubbers tend to become stiff below about −60 deg. C., but partially phenyl substituted low-temperature grades extend the useful range down to −100 deg. C. Of the rubbers with poor low-temperature performance, acrylic rubbers and Hypalon are generally unserviceable below about 0 deg. C. unless special compounding techniques may be employed. On the other hand, certain plastics such at p.t.f.e.,[11] which show limited flexibility at room temperature, may yet resist embrittlement down to very low temperatures indeed, although some loosening of current nomenclature is necessary for these materials to be regarded as "rubbers".

Practical Methods of Test

A number of standard tests are used to assess the low-temperature performance of rubber vulcanisates. Most of these tests suffer from the defect of trying to characterise the performance by means of a single parameter—a virtual impossibility, since several physical factors are involved, some of which are both stress and time dependent. The usual tests involve measurement of either torsional modulus at a given angular deflection, or the deflection produced by a given torque. Results are often expressed on a comparative scale, e.g. the Gehman T_{10} test records the temperature at which the torsional modulus at a given deflection has increased to ten times the value at +20 deg. C.; the Clash and Berg "cold flex temperature" is taken at an angular deflection of 200° for a specified torque. As is usual in rubber testing, the methods are rather arbitrary, and the results depend on the shape of test-piece, rate of cooling, etc., all of which must be accurately specified. A more serious limitation is the difficulty of application of such parameters to predict the performance of finished rubber articles under conditions of low-temperature service differing widely from those obtaining in the test.

Supplementary to these tests, data are often reported on: change of hardness with storage time at various temperatures (dependent on the rate of crystallisation); resilience/temperature relationships and other dynamic test results (dependent on segmental relaxation time); cold compression set; Young's modulus (again over a range of temperatures) (A.S.T.M.—D797-46); and, for extreme service, the brittle temperature (A.S.T.M.—D746-54T). A recent trend in rubber testing towards the measurement of more fundamental properties is reflected in the use of dilatometric methods is assessing rate of crystallisation.[12]

Armed with all this information, the rubber technologist is in a good position to distinguish between compounds, but it is usual to carry out service or "test rig" trials of actual components before making any final decision.

The Influence of Compounding on Low-temperature Flexibility

Having chosen a suitable base polymer which shows adequate resistance to crystallisation, the technologist may often improve its low-temperature performance by suitable compounding. The most common technique is to incorporate ester plasticisers, which depress both the glass transition temperature and the temperature at which crystallisation is most rapid; also, occasionally, the temperature of minimum resilience. However, the mechanical properties of highly plasticised polymers are often poor, and some plasticisers tend to migrate from the rubber, to leach out or to volatilise; these and other factors limit the amount which can be incorporated in a given mix. The most remarkable results may be achieved with highly polar polymers. For example, the rigid thermoplastic polyvinyl chloride (p.v.c.) can be blended with esters such as dioctyl sebacate to produce rubbery materials with cold flex temperatures down to below −70 deg. C. (see Fig. 6).[13] Another technique consists of blending together two polymers in order to maintain adequate elastic properties over a wider range of temperature than is possible with either material alone (see Fig. 7).[14]

It is obviously not practicable to detail here the compounding of every one of the large range of natural and synthetic rubbers in current use, and the interested reader is referred to recent publications.[15] The remainder of this article is devoted to describing a few examples of the low-temperature compounding of some common engineering rubbers:

NATURAL RUBBER (NR)—Brittle temperature (vulcanised) *ca.* −55 deg. C.; minimum resilience *ca.* −35 deg. C.; maximum rate of crystallisation *ca.* −26 deg. C. Use of crystallisation inhibited rubber is recommended—details and recommended compounding are included in a recent publication,[16] which suggests plasticised formulations for service down to −60 deg. C.

STYRENE-BUTADIENE RUBBER (SBR)—Brittle temperature *ca.* −50 deg. C. (depending on grade); minimum resilience *ca.* −20 deg. C.; little or no tendency to crystallise. Common to base formulations on low styrene (5/95) copolymers (1015 type) or on "oil extended" grades (OEP, 1700 types) where other considerations permit. Blends with natural rubber are useful, but there is little tendency to use ester plasticisers to reduce the brittle temperature, possibly for economic reasons.

BUTYL (IIR)—Characterised by high internal damping over a wide range of temperature (see Fig. 1), butyl is not a good polymer for mild low-temperature applications. It has been applied extensively as a non-resilient "damping" material. Below about −20 deg. C., however, other rubbers may show still poorer dynamic properties, and butyl comes into its own. High molecular weight polymer is recommended on account of its high plasticiser tolerance, and mineral-filled stocks may be compounded with brittle points down to −70 deg. C.[17]

NEOPRENE (CR)—Brittle point *ca.* −40 deg. C.; crystallisation dependent on grade; some grades, such as GN, stiffen perceptibly even on storage at room temperature—others, such as WRT, are copolymers which are fairly resistant to stiffening even at a temperature of −10 deg. C., when the crystallisation rate is a maximum.[18] (A special low-temperature grade, Neoprene WD, which will tolerate high plasticiser loadings has just been developed, but details are not available at the time of writing.)

Recommended formulations[19] for low-temperature service are based on blends of neoprene WRT (50), neoprene S (20), SBR 1015 (30) compounded with HAF black (65) to give adequate strength and plasticised with dioctyl sebacate (35). Such compositions have brittle points below −60 deg. C., and inclusion of sulphur in the vulcanising system effectively inhibits crystallisation, the time to half-crystallisation at −10 deg. C. being greater than forty days.

Problems may arise when these materials are used in contact with oils and solvents which tend to extract the plasticiser leading either to shrinkage or to replacement of the ester by a relatively poor plasticiser, namely, the oil.

NITRILE RUBBERS (NBR)—Brittle points are dependent on the percentage of acrylonitrile in the copolymer (35 per cent VCN → *ca.* −30 deg. C.); minimum resilience at *ca.* 0 deg. C.; little or no tendency to crystallise. Extreme low-temperature resistance is achieved by: (a) choosing a polymer with as low an acrylonitrile content as is permitted by the swelling of the rubber in the service oil; and (b) compounding with sebacate or other plasticisers in as high a loading as is permitted by the physical specification for the rubber, and with due regard to extractability. Brittle points below −60 deg. C. may be achieved.

POLYVINYL CHLORIDE (P.V.C.)—(Details given in Fig. 6.) Unvulcanisable under normal circumstances; lacking in resilience and elastic recovery throughout the temperature range. No tendency to crystallise. Flexibility is mainly dependent on the nature and concentration of the plasticiser.[20]

POLYURETHANE RUBBERS—A variety of results has been reported for different commercial polymers in this group, both with respect to the rigidity modulus/temperature relationship, and the resilience/temperature plot (see Fig. 8).[21] This may be due in part to differences in compounding.

SILICONE RUBBERS—The phenyl modified silicones are probably the best available rubbers for really low temperature operation. DTD specification No 818, Class M. specifies continuous operation below −75 deg. C.; in actual fact these rubbers can be used down to below −100 deg. C. (see Fig. 9).[22] Even general-purpose silicone rubbers are serviceable down to below −60 deg. C., and there are many applications in the aircraft and other industries. It is not possible to plasticise these polymers, and other compounding has only marginal effects.

FLUORO-RUBBERS—These rubbers are often used for oil-resistance at extremely high temperatures. They are generally rather inferior to the common organic rubbers at the low-temperature end of the scale, typical Viton compounds[23] having brittle points around −40 deg. C., and showing considerable stiffening in the Clash and Berg test at as high a temperature as −12 deg. C. No effective plasticisers are known. Among the better materials in this respect are the fluoro silicone rubbers, Silastomer LS53 and 63, which are serviceable down to below −60 deg. C.[24]

Conclusion

In conclusion, it may be added that the materials and methods outlined have proved quite adequate in dealing with the demands of designers and, in this respect, the position is rather better than at the other end of the temperature scale.

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NEW MATERIALS FOR AIRCRAFT

IT has long been known that the theoretical strength needed to pull apart the regularly arranged atoms of a material such as a metal is in the region of 1,000 t.s.i. For example, the theoretical strength of an aluminium alloy is some 100 times greater than the strength which is currently available to aircraft engineers, and this great disparity is something which clearly deserves the detailed study which it is now receiving. As the results of such studies on the strengths of all kinds of materials become available, they give strong support to theoretical estimates. Thus, Professor Silverman, in the U.S.A., has reported a glassy substance which, as a fibre, has a tensile strength around 500 t.s.i., a melting point of 2,000 deg. C. (with every indication that this can be raised to 2,500 deg C.) and moreover a high modulus of elasticity.* Similar results as regards strength have been reported in the U.K. for silica fibres and silica rods, and for metal crystals.

It is probable that most people regard any glassy substance as hopelessly brittle, and therefore useless as a structural material. But although a brittle material is one which fails catastrophically when the breaking point is reached, this does not mean that it cannot stretch or bend before it fails; in fact, it can—and does—have highly elastic properties, but it is not ductile.

A piece of silica about 0·03 in. dia. can be bent double at room temperature, the stretch on the outer edge being 8 per cent, representing a stress of some 500 t.s.i. The glass is perfectly elastic, and when released will spring back to its original shape. This property has been achieved by producing the fibre with a surface free of flaws (the interior being naturally flaw-free in an amorphous material). A slight touch on the unprotected surface of a stressed specimen will produce sufficient mechanical damage to cause the fibre to shatter. In other words, the brittleness normally associated with glass is due to surface flaws, and if these can be avoided in manufacture, and the surface then protected against damage, an elastic material of great strength is obtained.

On the assumption that we can look forward to the commercial production of silica and other fibres having a breaking stress around 500 t.s.i., there remains the problem of devising an engineering material to exploit these remarkable strengths. Conventional fibre glass embedded in plastic is a good commonplace example of the way in which a material can be used not only to protect the surfaces of the fibres, but also by means of its adhesive properties to prevent the propagation of cracks, thus forming a tough material. Low-density materials can also be constructed from fibres, not necessarily of very high strength, on the lines of the honeycomb structure. It would not seem unreasonable to forecast that a 40 per cent reduction in structure weight could be achieved in some instances, and a similar saving in cost.

* Product Engineering, *June 13, 1960*.

This article is an extract from a paper, "Aviation—the Next Stage", by Air Chief Marshal the Hon. Sir Ralph Cochran, presented at the eighteenth Brancker Memorial Lecture. It is reproduced by courtesy of the Institute of Transport, London.

DESIGN FORMULAE FOR THICK CYLINDERS

by A. ORMEROD, B.Sc., D.I.C., A.M.I.Mech.E. *

THE stresses set up in the wall of a thick cylinder by an internal pressure p consist of a tension p_H in the hoop (or circumferential) direction and a radial compression p_R, as shown in Fig. 1. The values of these stresses vary throughout the wall, and can be represented by the straight-line graph shown in Fig. 2. It will be seen that the base of the graph is marked off in values of $\frac{1}{R^2}$. The value of p_H is shown on the right-hand half, the value of p_R on the left-hand half. The graph is drawn by putting a straight line through the two known values of p_R, i.e. $p_R = p$ at the bore ($R = R_1$), and $p_R = 0$ at the exterior ($R = R_2$). The stresses in the material at some radius R can be read off, for example, at points A and B.

The highest stresses are in the material at the bore, where it can be seen by comparing similar triangles in Fig. 2 that

$$p_H = p \frac{\frac{1}{R_1^2} + \frac{1}{R_2^2}}{\frac{1}{R_1^2} - \frac{1}{R_2^2}}$$

or, if the "thickness ratio" $\frac{R_2}{R_1}$ is denoted by k

$$p_H = p \frac{k^2 + 1}{k^2 - 1}$$ tension, and $p_R = -p$ compression.

Design of Cylinder for Internal Pressure

The internal pressure p which is to be withstood will be known, as will also the tensile yield stress of the material available, and it is required to find the necessary thickness ratio k. The tensile yield stress will be denoted by fy, and it will be assumed that a suitable factor of safety has been incorporated in the figure.

As the material is subjected to a complex stress, it will be appropriate to use the "maximum shear stress" criterion for failure; that is the largest stress difference must not exceed fy, i.e.

$$p_H - p_R = fy$$

$$p \frac{k^2 + 1}{k^2 - 1} + p = fy$$

$$p \frac{2k^2}{k^2 - 1} = fy$$

or

$$\frac{2p}{fy} + \frac{1}{k^2} = 1 \qquad \ldots.(1)$$

which is the required formula.

If the cylinder has closed ends subjected to the internal pressure, there will be a tensile stress of $p \frac{1}{k^2-1}$ in the longitudinal direction. As this stress is intermediate in value between p_H and p_R at the bore, its presence does not affect the design.

The design formula (1) is shown plotted in Fig. 3. It will be seen that a cylinder of thickness ratio 2, for example, will withstand an internal pressure of $\frac{1}{3}$ fy. If the internal pressure to be resisted has a value much greater than this, the wall thickness has to be increased considerably. No single cylinder can be made to avoid yielding at the bore if the internal pressure approaches half the tensile yield stress of the material. The higher pressures can be catered for by designing a compound cylinder, and such a design will be considered later.

Stresses set up by External Pressure

The hoop and radial stresses set up in the wall of a cylinder by an external pressure are both compressive, as shown in Fig. 4. Their values at any point in the wall can be read from the graph shown in Fig. 6, which is constructed on the same principles as Fig. 2. The most highly stressed region is again the surface of the bore, where

$$p^H = p \frac{2k^2}{k^2-1}$$ compression, and $p_R = 0$.

Design of Cylinder for External Pressure

Applying the maximum shear stress criterion leads to the same condition as was found for internal pressure, i.e.

$$p \frac{2k^2}{k^2-1} = fy,$$

and formula (1) and Fig. 3 can be used for design.

A cylinder with closed ends subjected to the external pressure p will have a compressive stress of value $p \frac{k^2}{k^2-1}$ in the longitudinal direction. As this stress is intermediate in value between p_H and p_R at the bore, its presence does not affect the design.

Stresses in Compound Cylinders

If the design of a single cylinder to withstand internal pressure calls for excessive wall thickness or for very high strength material, it may be more economical to use a compound cylinder consisting of an inner tube with an outer tube, or a number of rings, forced over it. The force fit sets up building stresses consisting of a compressive hoop stress in the inner cylinder and a tensile hoop stress in the outer cylinder. These building stresses, when added to the tensile hoop stresses set up by the pressure of the working fluid, result in a more even distribution of stress throughout the wall, and therefore a more efficient design.

Fig. 7 represents the two cylinders built together with a pressure p_S set up at the common surface by the force fit. Figs. 8a and 8b show the building stresses in the cylinders due to p_S. Fig. 8c shows the stresses which would be set up by an internal fluid pressure p in the absence of any building stresses. In Fig. 8d the building stresses have been superimposed on the fluid pressure stresses to show the final net stresses. The highly stressed regions are the inner surfaces of the two cylinders, and the aim of a design is to equalise the shear stresses in these two regions by arranging to provide building stresses of the right order.

* Royal Military College of Science.

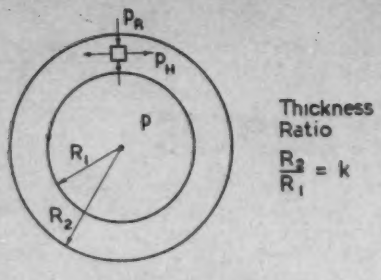


Fig . 1. Stresses in the Wall of a Cylinder with Internal Pressure

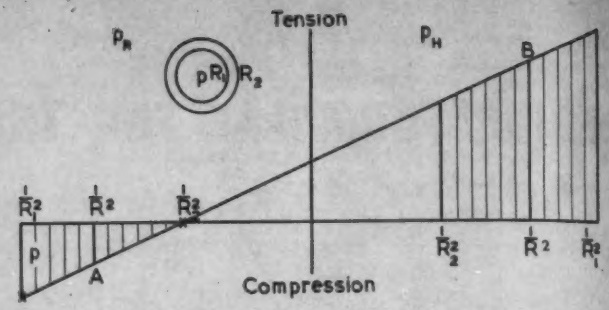


Fig . 2. Cylinder with Internal Pressure Graph of Stresses

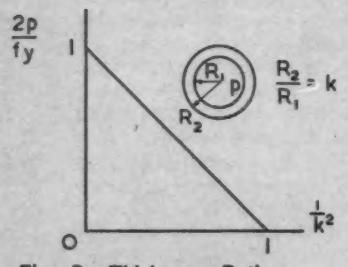


Fig . 3. Thickness Ratio Required for Different Pressure

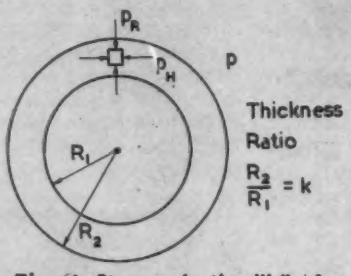


Fig . 4. Stresses in the Wall of a Cylinder with External Pressure

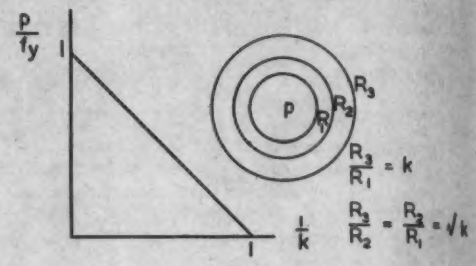


Fig . 5

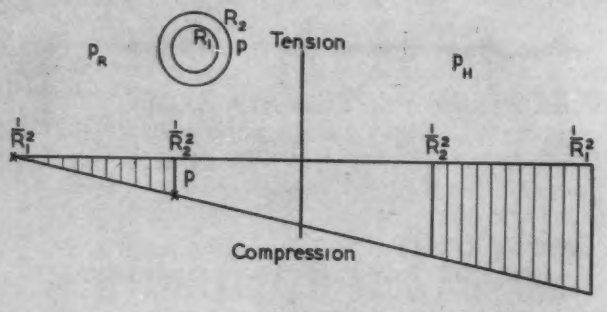


Fig 6. Cylinder with External Pressure. Graph of Stresses

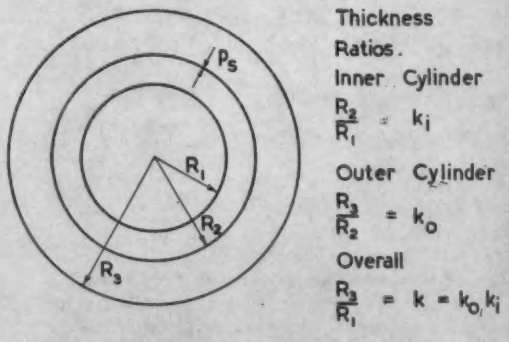
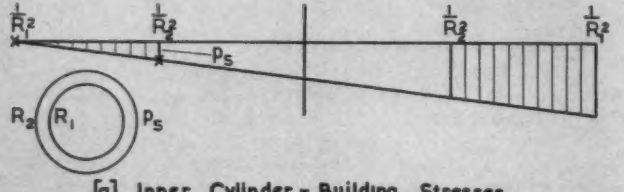
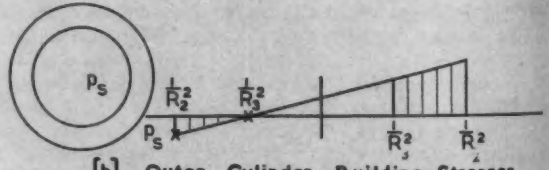


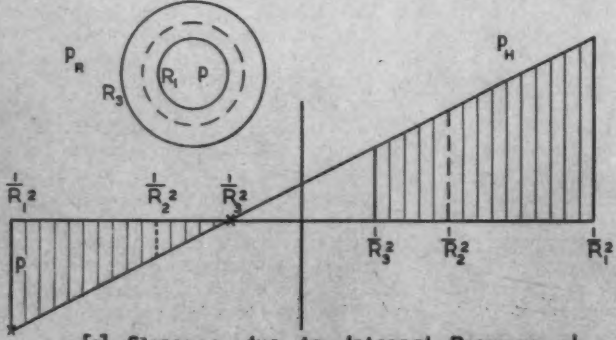
Fig . 7. Compound Cylinder. Pressure at Common Surface due to Building = p_s



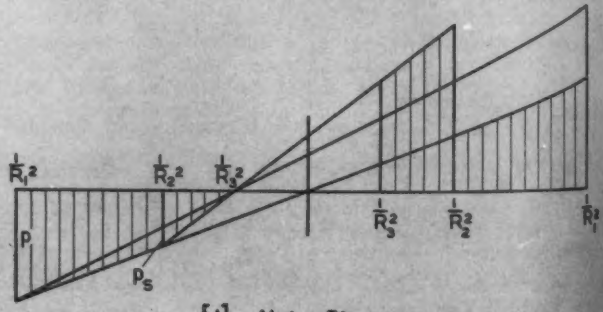
[a] Inner Cylinder - Building Stresses



[b] Outer Cylinder - Building Stresses



[c] Stresses due to Internal Pressure p'



[d] Net Stresses

Fig . 8. Stresses in Compound Cylinder

Design of a Compound Cylinder

In order to keep the discussion within reasonable bounds, it will be limited to considering a design employing two tubes only with no longitudinal stress, the tubes being made from material of the same strength and elastic properties. If the thickness ratios are denoted as in Fig. 7, viz.

inner tube $\frac{R_2}{R_1} = k_i$, outer tube $\frac{R_3}{R_2} = k_0$, and compound tube, overall thickness ratio $\frac{R_3}{R_1} = k$, it is apparent that $k_i\, k_0 = k$.

As the tubes are to be made of similar material, the optimum design will be obtained when $k_i = k_0 = \sqrt{k}$.

The object is to determine, for a given fluid pressure p and tensile yield strength fy (which includes a factor of safety), the necessary thickness ratio k and the interference allowance for building. The relevant stresses can be obtained from the diagrams shown in Fig. 8, and are:

Bore of Inner Cylinder

Due to building:

$$p_H = -p_S \frac{2k_i^2}{k_i^2-1} = -p_S \frac{2k}{k-1}, \text{ and } p_R = 0.$$

Due to fluid pressure:

$$p_H = p \frac{k^2+1}{k^2-1}, \text{ and } p_R = -p.$$

Net stresses:

$$p_H = p \frac{k^2+1}{k^2-1} - p_S \frac{2k}{k-1}, \text{ and } p_R = -p.$$

$$p_H - p_R = p \frac{2k^2}{k^2-1} - p_S \frac{2k}{k-1}.$$

Bore of Outer Cylinder

Due to building:

$$p_H = +p_S \frac{k_0^2+1}{k_0^2-1} = p_S \frac{k+1}{k-1}, \text{ and } p_R = -p_S.$$

Due to fluid pressure:

$$p_H = +p \frac{k_0^2+1}{k^2-1} = p \frac{k+1}{k^2-1},$$

$$\text{and } p_R = -p \frac{k_0^2-1}{k^2-1} = -p \frac{k-1}{k^2-1}.$$

Net stresses:

$$p_H = p \frac{k+1}{k^2-1} + p_S \frac{k+1}{k-1},$$

$$\text{and } p_R = -p \frac{k-1}{k^2-1} - p_S.$$

$$p_H - p_R = p \frac{2k}{k^2-1} + p_S \frac{2k}{k-1}.$$

As the shear stress ($= \frac{1}{2}(p_H - p_R)$) at the two positions is to have the same value,

$$p \frac{k^2}{k^2-1} - p_S \frac{k}{k-1} = p \frac{k}{k^2-1} + p_S \frac{k}{k-1},$$

or

$$p_S = \frac{p}{2} \frac{k-1}{k+1} \qquad \ldots.(2)$$

Substituting for p_S in the expression for $(p_H - p_R)$ at the bore of the inner cylinder gives

$$p_H - p_R = p \cdot \frac{2k^2}{k^2-1} - \frac{p}{2} \frac{k-1}{k+1} \cdot \frac{2k}{k-1}$$

$$= p \cdot \frac{k}{k-1}$$

Using the criterion for no yield ($p_H - p_R = fy$) gives

$$p \frac{k}{k-1} = fy, \text{ or } \frac{p}{fy} + \frac{1}{k} = 1 \qquad \ldots.(3)$$

and this is the required formula for k.

The formula is shown plotted in Fig. 5. From this relation it may be seen, for example, that a compound cylinder made of two tubes each with a thickness ratio of 2, giving an overall thickness ratio of 4, will withstand an internal pressure of $\frac{1}{4}$ fy. This pressure is, of course, well outside the range of the simple single cylinder.

Interference Allowance

The pressure to be set up at the common surface by building is $p_S = \frac{p}{2} \frac{k-1}{k+1}$. The conditions arising at the common surface due to this pressure are:

Inner Cylinder

$$p_H = -p_S \frac{k_i^2+1}{k_i^2-1} = -p_S \frac{k+1}{k-1}, \text{ and } p_R = -p_S.$$

$$\text{Hoop strain} = -\frac{p_S}{E}\left(\frac{k+1}{k-1} - \frac{1}{m}\right)$$

where $\frac{1}{m}$ is Poisson's ratio.

Outer Cylinder

$$p_H = p_S \frac{k_0^2+1}{k_0^2-1} = p_S \frac{k+1}{k-1}, \text{ and } p_R = -p_S.$$

$$\text{Hoop strain} = \frac{p_S}{E}\left(\frac{k+1}{k-1} + \frac{1}{m}\right).$$

The interference allowance $\frac{\delta R_2}{R_2}$ is the sum of the compressive hoop strain of the inner cylinder and the tensile hoop strain of the outer cylinder, i.e.

$$\frac{\delta R_2}{R_2} = \frac{2p_S}{E} \cdot \frac{k+1}{k-1} = \frac{p}{E} \qquad \ldots.(4)$$

Conclusion

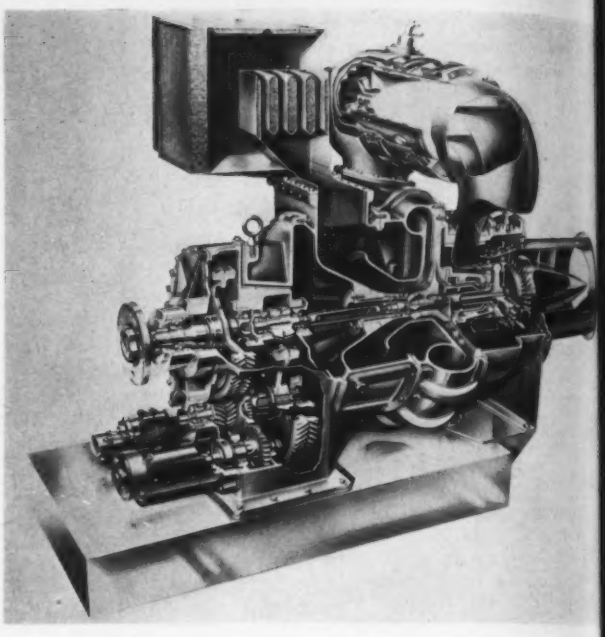
For really high pressures, compound cylinders may be designed made up of more than two tubes. Such a design calls for careful consideration of the building technique. Cylinders have also been made up by using layers of high tensile wire wound at predetermined tensions on the inner tube. More recently the tendency has been to use a single tube "autofrettaged", i.e. having initial wall stresses set up by overstraining the cylinder during manufacture by applying a high internal pressure. Such designs are the field of the specialist. For normal work the rules deduced above provide a useful guide. They are repeated for easy reference:

For a single cylinder of material having a working tensile stress fy to withstand a pressure p applied internally or externally, the thickness ratio $k \left(= \frac{\text{outside diameter}}{\text{inside diameter}} \right)$ is given by the relation $\frac{2p}{fy} + \frac{1}{k^2} = 1.$

For a compound cylinder made of two tubes each having the same thickness ratio $\sqrt{k}$, the overall thickness ratio k is given by the relation $\frac{p}{fy} + \frac{1}{k} = 1,$

and the building interference is $\frac{\delta R}{R} = \frac{p}{E}.$

Fig. 1. Sectional view of the new Austin 250 gas turbine, showing its simple layout and robust construction.



DEVELOPMENTS IN GAS TURBINES

The successful development of the aircraft gas turbine has shown its advantages over the reciprocating engine as regards weight, bulk and simplicity.

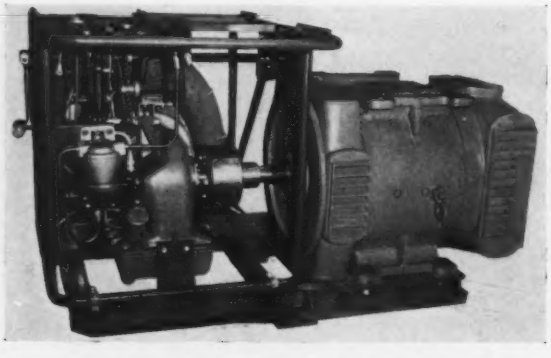
Following the successful experiment in the production of a 3 MW. Proteus-powered generating set, **Bristol Siddeley** have put forward proposals for a 15-20 MW. set using the Olympus turbo-jet aero engine as a gas generator to energise a free turbine coupled directly to an electric generator. This plant is intended for power boosts of short durations. The use of low capital cost gas-turbine generating equipment for peak lopping duty shows considerable economy, and cost savings are said to be possible by using this type of equipment for a decentralised peak lopping policy.

The EM27 gas turbine plant installed by **The English Electric Co** at the Esso Petroleum Co. Fawley refinery, in Hants., is providing additional evidence of the inherent reliability and very low maintenance requirements of long-life industrial gas turbine machinery.

In the plant at Fawley the EM27 turbine is directly coupled to a Clark multi-stage gas compressor, and is fuelled by refinery gases; a waste heat boiler in the turbine's exhaust system recovers sufficient heat to raise 18,000 lb. of steam per hr. at 125 p.s.i.g. Overall efficiency of the turbine-boiler combination at full load is over 60 per cent.

The turbine has accumulated some 17,000 hr. operation in just over two years of commercial service. In its total running time of 13,761 hr. the gas turbine has only been out of commission for about 38 hr. due to minor faults. This represents an availability factor of 99·7 per cent. The turbine has run for 13,761 hr. out of a possible total of 15,596 hr., i.e., 88·2 per cent of the available time. The longest non-stop run has been 4,111 hr., or approximately six months.

Fig. 2. 50-h.p. Perkins Mars gas-turbine-driven d.c. generator.



Two new gas turbine generating sets will be shown for the first time in Britain by **Perkins Gas Turbines Ltd.** at the Engineering, Marine, Welding and Nuclear Energy Exhibition at Olympia.

The Mars gas turbine is coupled to a 30 kW. d.c. generator by means of a Twiflex clutch coupling. Excluding fuel tanks, the overall weight is approximately 875 lb. The gas turbine is supported in its own frame, and is hand started by means of a single hand crank. Engine acceleration is automatic after cranking to an output speed of approximately 1,000 r.p.m., the fuel valve having been turned on at a speed of 500 r.p.m. The clutch enables the inertia of the generator to be out of engagement during the hand cranking and during subsequent acceleration up to an output speed of about 2,700 r.p.m. At this speed the clutch engages and the engine and generator further accelerate automatically to a rated speed of 4,400 r.p.m.

The Solar Jupiter gas turbine is coupled to a 330 kW. d.c. generator. This turbine is rated at 525 b.h.p., and fitted with a combustion air starter capable of starting the engine in 10 sec. With the generator it weighs approximately 4¼ tons including base plate, and occupies a volume of some 400 cu. ft., which makes it an ideal unit for providing ship-board auxiliary power or emergency power.

Another new product specifically designed for industrial applications is the **Austin** 250 b.h.p. gas turbine (see Fig. 1). This is a single shaft machine in which the turbine rotor drives the centrifugal compressor at a speed of 29,000 r.p.m. to give a pressure ratio of 3·5 : 1, the power being taken out from the rotor assembly through a two-step layshaft reduction gear using double helical gears for long life. The output speed is reduced to 1,500 r.p.m. for 50 c/s electricity generation, but the unit can be supplied for any required speed.

With the relatively high cycle temperature of 800 deg. C. used in this unit, a high overall thermal utilisation may be achieved in applications where use can be made of the exhaust heat for process work. The turbine's ability to use cheap fuels such as methane and other by-product fuels also gives it many applications.

PROBLEMS IN DESIGN

Problem No. 15 (January): In a piece of display apparatus it is necessary to provide a means whereby a slowly rotating shaft will cause a display disc, having the same axis of rotation, to move round in a series of dwells.

Data: display disc, approximately 18 in. in dia., completes one revolution per minute, this being accomplished in twelve dwells of approx 5 sec. each. Since the display is suspended, no obvious means of torque constraint must be apparent. The motive power for the shaft will be an f.h.p. motor, concealed overhead.

A striking feature of many of the entries we receive for our monthly problem is the bias shown towards either heavy or light engineering design. It is tempting, on occasion, to hazard a guess as to the kind of work some readers are engaged upon, whether they have had a good practical background and so forth. Occasionally, a good basic idea is drawn in a way that suggests a mainly academic training with little experience of how components are best designed for production. Entries from those having a tool design background tend to be workmanlike but on the heavy side, the emphasis being on how to make rather than how to design. What is rare, in our experience, is to find a designer who, confronted with a problem in machine or tool design, produces something rugged and robust, yet who could, if the occasion demanded, design a mechanism for, say, a domestic appliance where cost of manufacture was a prime consideration. The good all-rounder must necessarily be rare in an age of specialisation. We feel, nevertheless, that designers and draughtsmen should study how their counterparts in other industries tackle similar problems.

The above problem, being one of rotary indexing, at once suggests some sort of Geneva or barrel cam solution, and two satisfactory entries were received in the former category. **L. Woronowski** chose to use a shaft rotating at 12 r.p.m. and a four-slot Geneva wheel attached to a spur pinion driving a 3 : 1 gear. His drive shaft is carried inside a torque restraining tube.

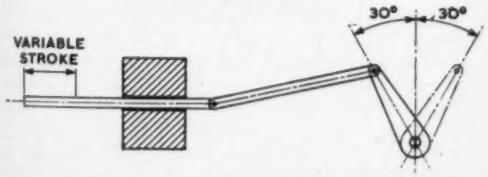
In **J. A. Barnes'** solution the drive shaft *1* is also encased in a stationary tube *2*, and carries a pinion *3* meshing with gear *4* which is free to rotate about pivot *5*. This pivot is fixed to a plate *6*, which is held to an upper plate *8* by three shouldered studs and distance pieces *7*. This upper plate is fixed to the torque restraining tube *2*. Co-axial with gear *4*, and driven by it, is the driving roller *9* of a twelve-station Geneva wheel *10* fixed to the display plate by countersunk head screws and running on the boss *11* of the upper plate *8*. Input shaft speed would be 48 r.p.m.

M. L. S. Flint's barrel cam solution is well engineered and fundamentally sound. It would provide an absolutely positive indexing motion, and would be a sound idea if the machine were used for displaying very heavy pieces of equipment. Barrel cams can be designed to give various kinds of acceleration and deceleration as indexing starts and stops. In a piece of display apparatus for a show stand or shop window, however, it would be rather costly. Barrel cams are hard to cut unless special machines are available. We feel, therefore, that although Mr. Flint's entry is unquestionably sound, it employs a principle better suited to the indexing of a machine tool turntable, where absolute accuracy is necessary.

The ingenious solution from **J. F. Jackson,** which is self-explanatory, is also rather costly for the duty to be performed. The principle employed is, however, worth

PROBLEM IN DESIGN No. 19

Here is this month's problem



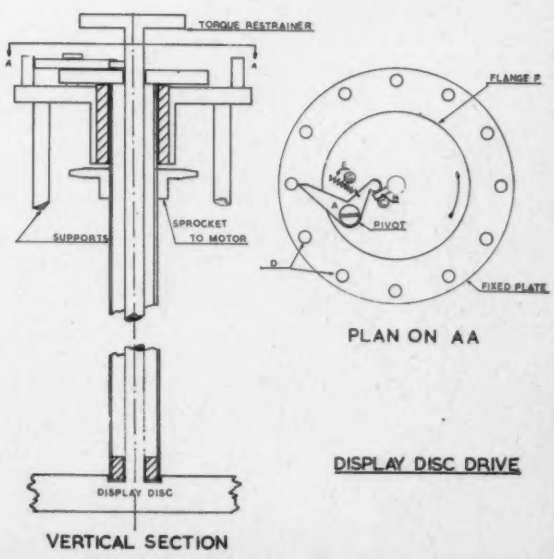
In a special-purpose machine a reciprocating lever causes a sliding member to move to and fro. As the angular reciprocation of the lever cannot be varied, adjustment of the length of stroke of the sliding member is difficult. Although this can be accomplished by slotting the lever, thus making the connecting rod pivot point adjustable and giving longer or shorter strokes, the operation of making the adjustment involves stopping the machine.

Suggest an alternative linkage which will enable adjustment of the stroke length to be carried out while the machine is running.

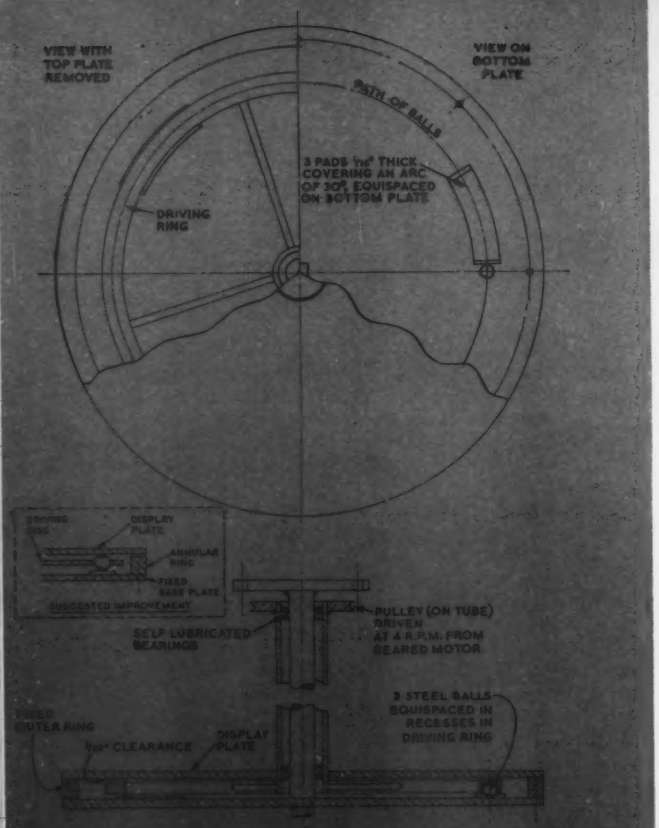
Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12 × 12 in., please!), to the Editor, "Problems in Design No.19 (May)". Closing date June 20.

Apologies are made for the incorrect closing date (March 20) given last month—this should of course have read May 20.

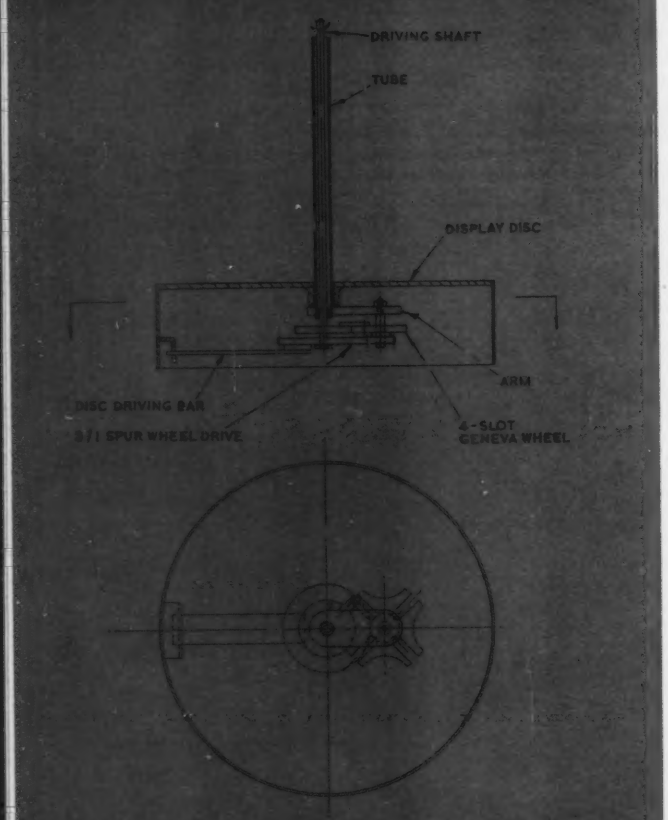
A. G. HICKS



DISPLAY DISC DRIVE


VIEW WITH TOP PLATE REMOVED
VIEW ON BOTTOM PLATE
PATH OF BALLS
3 PADS 1/16" THICK COVERING AN ARC OF 30° EQUISPACED ON BOTTOM PLATE
DRIVING RING
DRIVING DISC
DISPLAY PLATE
ANNULAR RING
FIXED BASE PLATE
SUGGESTED IMPROVEMENT
SELF LUBRICATED BEARINGS
PULLEY (ON TUBE) DRIVEN AT 4 R.P.M. FROM GEARED MOTOR
3 STEEL BALLS EQUISPACED IN RECESSES IN DRIVING RING
FIXED OUTER RING
1/16" CLEARANCE
DISPLAY PLATE

F. SEDDON



L. WORONOWSKI

remembering. In this case the whole mechanism, including the motor, reduction gear and torque constraint would be concealed overhead and a long shaft would carry the display disc. A part gear, integral with the input shaft which revolves at 6 r.p.m., engages with a pinion from which eight of the normal complement of twelve teeth have been removed. The two teeth on the part gear rotate the pinion through 90° for every 180° of its own rotation. This occurs every 5 sec. The lower portion of the pinion (section *D-D*) is provided with the full number of teeth, and engages the output shaft which is co-axial with the input. It will be seen from the sections showing part gears that the output is prevented from rotating during the dwell periods. The output shaft is thus indexed through twelve positions 30° apart every minute, the indexing time being 5-6 sec. and the dwell time $4\frac{1}{6}$ sec. per position.

The cunning behind this design is that the unusual requirement of sudden indexing is met. A still longer period of dwell could be provided by having only one tooth in the input gear (section *A-A*), which would then revolve at 12 r.p.m. The rather fierce acceleration might necessitate a lighter display disc with less inertia.

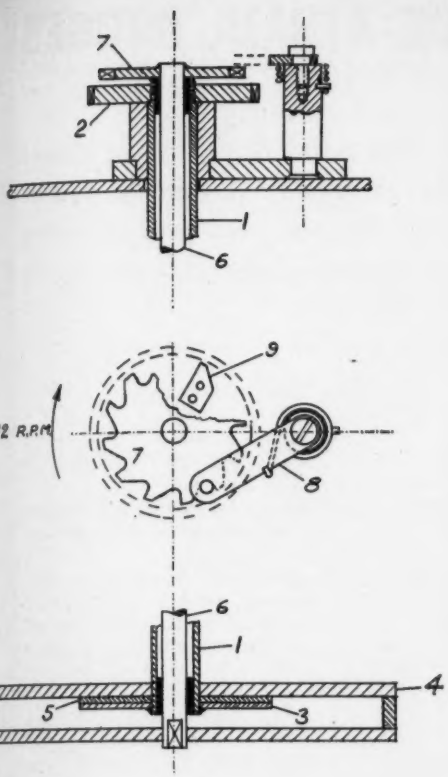
As the mechanism was only for a machine intended for display purposes, some entries were received which, unlike the foregoing, were designed for simplicity and lightness.

W. Brown's neat entry employs a hollow shaft driven at 12 r.p.m. by the gearwheel *2*. To the bottom of this shaft is fixed a driving disc *3*, and the display disc rests on the interposed friction ring *5*. A twelve-tooth ratchet *7*, mounted on the concentric inner shaft *6*, is caused to move every 5 sec. by cam block *9* which is pinned to the input driving gear. This mechanism gives approximately $4\frac{1}{2}$-sec. dwell. The only minor disadvantage, which would probably not matter in a device rotating so slowly, is that the motor is operating against friction except during the indexing operation.

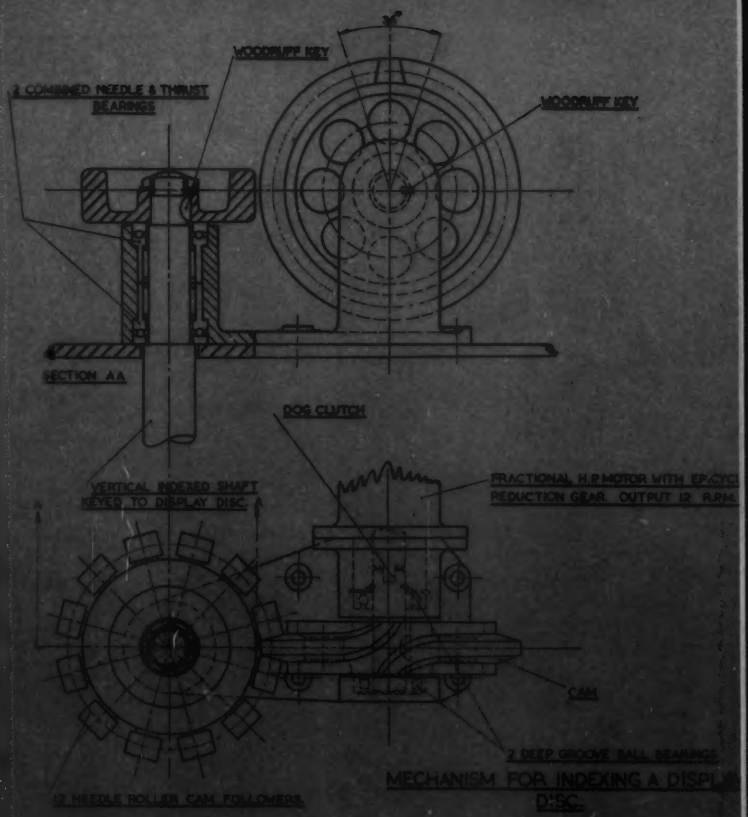
The same criticism applies to the entry from **A. G. Hicks.** In this case an overhead friction pad would be necessary to bear against the torque restrainer shown. Lever *A* is pivoted on the rotating flange *F*, and presses with its inner end against stud *B* when its outer end is in contact with the pins *D* arranged equally around the fixed plate. The stop *C* is placed so that the stud *B* is trapped between it and the inner end of the lever at the end of its stroke, so that it serves to arrest the display disc and bring it to the same speed as the rotating shaft. The lever *A* is returned by spring *E* to the back stop *G* when the lever passes each of the pins *D*.

Of the ratchet-type entries, we consider that from **F. Seddon** the simplest and best. It avoids the need for the motor to run against a frictional constraint. A fixed bottom plate, to the upper side of which is fitted an annular ring, is suspended by a rod having at its upper end a flange for attachment to the ceiling. A spoked driving ring, containing three equi-spaced balls fitted in recesses, rests on the bottom plate and is driven by a tubular shaft to which a driving pulley is fitted. The tube is caused to revolve at 4 r.p.m. Self-lubricated bearing bushes enable the tube to turn about the central fixed rod. Three pads $\frac{1}{16}$ in. thick, having a short incline at each end, and occupying 30° of arc at the same radius as the balls, cause the balls to rise, thus lifting the driving ring, and this ring lifts the display disc. Somewhat similar ideas came from **J. Elsworth** and **A. D. Watt,** and a rather more elaborate one from **C. S. Netscher.**

We consider that Mr. Seddon's simple and elegant idea could be improved (see sketch) by the driving disc being in the form of a drilled plate through which the balls would protrude on each side. The balls or rollers would then make contact with the display plate and provide rolling rather than sliding friction. With this arrangement, pads occupying only 15° of arc only would be necessary, thus halving the time required to perform the indexing operation.



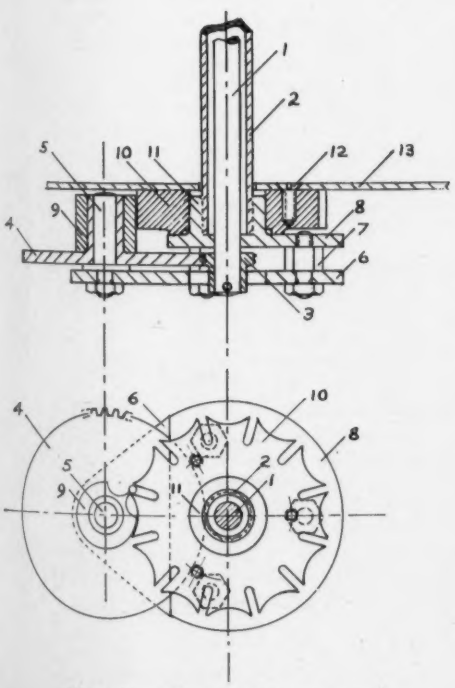
W. BROWN


WOODRUFF KEY
2 COMBINED NEEDLE & THRUST BEARINGS
WOODRUFF KEY
SECTION AA
DOG CLUTCH
VERTICAL INDEXED SHAFT KEYED TO DISPLAY DISC
FRACTIONAL H.P. MOTOR WITH EPICYCLIC REDUCTION GEAR. OUTPUT 12 R.P.M.
CAM
2 DEEP GROOVE BALL BEARINGS
12 NEEDLE ROLLER CAM FOLLOWERS

MECHANISM FOR INDEXING A DISPLAY DISC.

M. L. S. PLINT

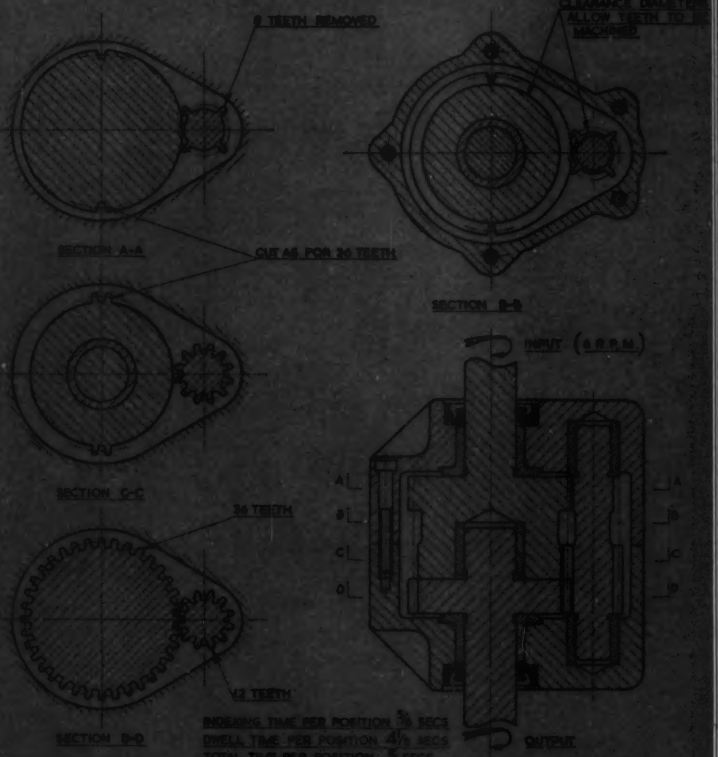
J. A. BARNES



Plan View (Display Table Removed).

J. F. JACKSON

MECHANISM SHOWN IN MIDDLE OF DWELL PERIOD



ELECTRICAL RESISTANCE STRAIN GAUGES

The use of resistance strain gauges for determining stresses in both static and dynamic structures provides the designer with essential information—this article sets out the principles involved, and indicates the various types of gauge available

by J. EDWARDS, B.Sc.

DUE to the complexity of many modern structures, their safety and efficiency can only be determined by the measurement of working stresses. The measurement of strain provides a reliable method of stress determination. Many types of strain measuring devices exist, but only the resistance strain gauge provides a relatively cheap and robust method capable of operation under various conditions of temperature and humidity, and suitable for automatic recording, thus allowing permanent installation in remote and inaccessible positions.

The basic physical phenomenon underlying the operation of a strain gauge is the linear relationship that exists between the change in electrical resistance of a wire and the change in mechanical strain, i.e.

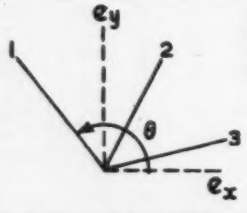
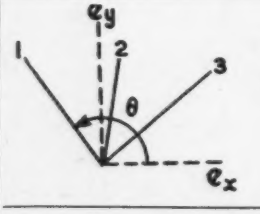
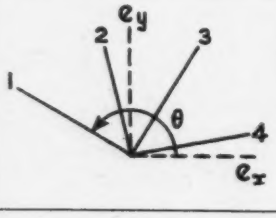
$$\frac{\delta R}{R} = K\,\frac{\delta L}{L} = Ke \qquad \ldots . (1)$$

The factor K is known as the gauge factor, and is a constant for each wire material. For most materials K is approximately 2, but values as high as 5·5 do exist.

The modern strain gauge consists of a length of fine wire wound into a suitable grid shape and cemented on to a paper carrier. When the gauge is cemented to a structure, changes in strain in the material under the gauge are also applied to the gauge wire, thus producing a change of electrical resistance from which the strain can be determined.

Three common types of grid are shown in Fig. 1. Type (a) is made by winding a length of 0·001-in.-dia. wire around pins and cementing to a paper base. The pins are then removed and robust leads welded in position and firmly cemented down. Type (b) is made by winding a length of 0·001-in.-dia. wire around a cylindrical paper former and cementing in position. The former is then flattened, robust leads welded in position, and the whole assembly cemented

Table 1. Formulæ for the calculation of principal strains from strain gauge rosettes

Form	Tan. 2θ	e_x and e_y (e_x Positive Sign)
 Equiangular 60° Rosette (see Fig. 7c)	$\dfrac{\sqrt{3}(e_2 - e_3)}{2e_1 - e_2 - e_3}$	$\dfrac{e_1+e_2+e_3}{3} \pm \sqrt{\dfrac{2}{3}}\sqrt{(e_1-e_2)^2+(e_2-e_3)^2+(e_1+e_3)^2}$
 Rectangular 45° Rosette (see Figs. 7a and b)	$\dfrac{2e_2 - e_1 - e_3}{e_1 - e_3}$	$\dfrac{e_1+e_3}{2} \pm \sqrt{\tfrac{1}{2}[(e_1-e_2)^2+(e_2-e_3)^2]}$
 Four-gauge 45° Rosette (see Fig. 7d)	$\dfrac{e_2 - e_4}{e_1 - e_3}$	$\dfrac{e_1+e_2+e_3+e_4}{4} \pm \tfrac{1}{2}\sqrt{(e_1-e_3)^2+(e_2-e_4)^2}$

Nomenclature

e = mechanical strain;
e_1, e_2, e_3, = mechanical strains in direction of gauges 1, 2 and 3;
e_x, e_y = principal strains in directions x and y;
E = Young's modulus;
f = stress;
K = gauge factor;
L = original length of wire;
δL = change in length of wire due to applied strain;
R = resistance of active strain gauge;
$R_{1,\ 2,\ 3,\ x,\ y}$ = resistance of active gauges in directions 1, 2, 3, x and y;
δR = change of resistance of active gauge due to strain;
r = slide wire resistance;
δr = resistance change in fixed arms necessary to balance bridge;
P, Q = resistance of fixed arms of bridge;
S = resistance of compensating arm of bridge;
X, Y = maximum and minimum principal stresses respectively;
σ = Poisson's ratio;
θ = direction of maximum principal stress relative to gauge 1.

on to a paper base. For type (c) the grid is accurately drawn on white paper and photographed. The foil for the grid is covered with resin on one side and photographic emulsion on the other. The negative is placed in contact with the emulsion and exposed to ultra-violet light, after which an etching solution is applied. The areas which have not been affected by the light, i.e. the dark parts of the negative, are removed by the solution, thus leaving the required grid attached to a resin base. Further information on foil gauges can be found in a booklet entitled "The Technograph Foil Strain Gauge", issued by Technograph Electronic Products Ltd.

Advance, Nichrome V and Karma (all three made by British Driver-Harris Co. Ltd.) are the usual materials used for strain gauge grids, since all have high yield points and stable properties. Advance and Karma have very low temperature coefficients of resistance, but Karma has a much higher resistivity than Advance. Nichrome V has a fairly high coefficient of resistance, but is capable of operating at higher temperatures and has a high resistivity. Annealed wire is always used, as it does not coil up when removed from the spool, but it suffers slightly from the effects of work hardening during manufacture and subsequent strains. These effects can, however, be eliminated by special stress-relieving treatments.

Strain gauges are made in various lengths from approximately $\frac{1}{8}$ to $1\frac{1}{2}$ in., with resistances varying from 50 to 1,000 ohms or even 10,000 ohms in some cases. The lower resistances are usually used for static measurements, while higher resistances are used for dynamic work.

Measurement of Resistance Changes

The simplest and perhaps the most accurate method of measuring the change of resistance of a gauge is by using a null balanced Wheatstone bridge circuit, as shown in Fig. 3. This method is suitable for the measurement of static strains only, due to the time required to rebalance the bridge. When the bridge is balanced no current flows in the galvanometer, and the following relationship holds:

$$\frac{R}{S}=\frac{P}{Q} \qquad \ldots.(2)$$

If the gauge resistance now increases to $R + \delta R$ the bridge can be rebalanced by increasing resistance P to $P + \delta r$, thus

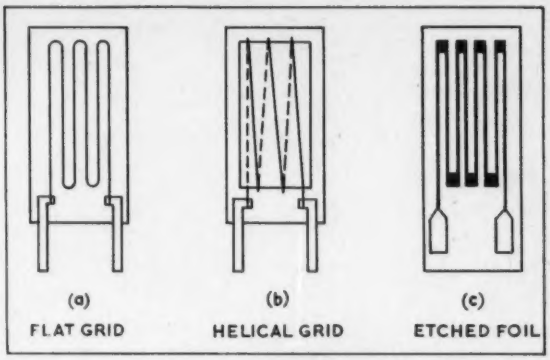


Fig. 1. Various types of strain gauge grid.

Fig. 2. Winding a flat grid type gauge (at A. V. Roe Ltd.).

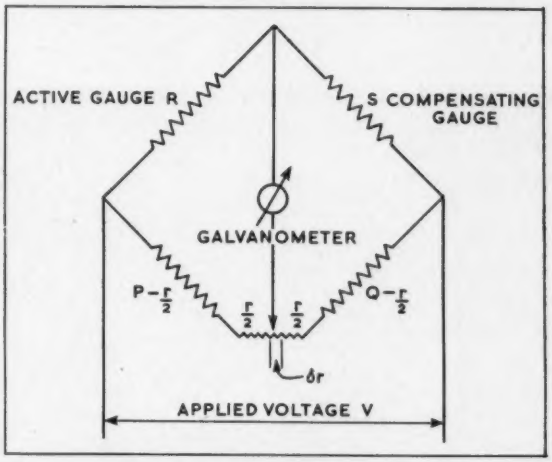


Fig. 3. Null balance Wheatstone bridge.

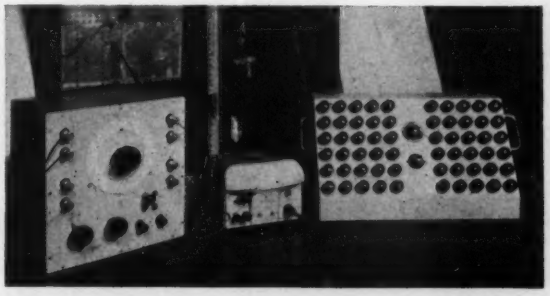


Fig. 4. Typical measuring equipment for static work.

Fig. 5. Typical measuring equipment for dynamic work.

reducing resistance Q to $Q - \delta r$. Equation (2) becomes

$$\frac{R + \delta R}{S} = \frac{P + \delta r}{Q - \delta r} \quad \ldots . (3)$$

In a normal strain gauge installation the resistance S is an unstrained gauge identical to the active gauge R, and the resistances P and Q are equal.
Hence equation (3) now becomes

$$\frac{R + \delta R}{R} = \frac{P + \delta r}{P - \delta r} \quad \ldots . (4)$$

$$\text{i.e. } 1 + \frac{\delta R}{R} = 1 + \frac{2\delta r}{P} + \frac{2\delta r^2}{P^2} + \ldots ,$$

$$\text{and } \frac{\delta R}{R} = 2\left(\frac{\delta r}{P} + \frac{\delta r^2}{P^2} + \ldots\right).$$

$$\text{Therefore } \frac{\delta R}{R} = \frac{2\delta r}{P} \quad \ldots . (5)$$

Hence the slidewire r can be calibrated directly in terms of change of resistance of the active gauge. In practice, P and Q are usually 100 ohms, and r about 0·5 ohms, giving a measuring range of $\pm 0{\cdot}5$ per cent for $\frac{\delta R}{R}$.

Sometimes the slidewire is omitted, and the change of resistance of the active gauge is determined directly in terms of the galvanometer deflection. This method is satisfactory but usually rather slow, as the sensitive galvanometers normally used take some time to settle.

If dynamic strains are to be measured by this method a Duddell galvanometer must be used. This is a short-period galvanometer of high sensitivity, and is usually built into an automatic recording device producing a trace on film or light-sensitive paper. An ultra-violet recorder is particularly useful in this respect, presenting the answer for immediate inspection without the use of photographic processes.

The higher frequency galvanometers are not usually sufficiently sensitive for use directly across the bridge output without amplification. A.c. amplifiers provide the simplest form of amplification, but their use is limited by their inability to handle d.c. signals. Therefore, wherever static strains are present, either a d.c. amplifier or an a.c. chopper amplifier must be used. A chopper amplifier is an orthodox a.c. amplifier in which the input is intermittently earthed to produce a square waveform, thus allowing amplification by the a.c. amplifier.

An alternative method is to supply the bridge with a high-frequency a.c. carrier voltage, thus producing a modulated a.c. output which can be amplified by an a.c. amplifier, demodulated and fed directly to a recorder. This type of recording is usually limited to a frequency about one-twentieth of the carrier frequency.

Alternative methods of recording are provided by the pen recorder and cathode ray oscilloscope. Pen recorders are limited to low frequencies, however, and the trace amplitude must be small due to the large inertia effects of the pen.

Table 2. Strain gauge transducers

Manufacturer	Type	Remarks
PRESSURE MEASUREMENT		
Southern Instruments Ltd.	G207A	Miniature type. Various ranges up to 10,000 p.s.i.
	G207B	Larger version of type G207A.
	G207C	Similar to type B. Various ranges up to 78,400 p.s.i.
	G237	Various ranges up to 45,000 p.s.i. Temperature compensated.
	G243and G243S	Designed for engine indication. Various ranges up to 6,000 p.s.i.
	G289	Mainly for dynamic pressures. Various ranges up to 1,000 p.s.i
J. Langham-Thompson Ltd.	BP1	Various ranges up to 2,000 p.s.i. Temperature compensated.
	BP 3	Various ranges to 20,000 p.s.i. Temperature compensated.
	UP	Various ranges from ± 10 in. of water up to ±500 p.s.i. Temperature compensated.
FORCE MEASUREMENT		
J. Langham-Thompson Ltd.	348	Ring dynamometer. Various force ranges up to 10,000 lb.
	349	Link dynamometer. Various ranges up to 100,000 lb.
	UF1	Various ranges from 4 oz. to 2 lb.
Philips Ltd. (Research & Control Instruments Ltd.)	PR9226	Load cell. Various ranges from 2-50 tons.
	PR9227	Measurement of tensile forces from 400-4,400 lb.
	PR9228	Dynamometer. Two ranges—110 and 220 lb.
	PR9239	Concrete deformation pick-up. Operating range 0-2,000 micro-strain.
WEIGHT MEASUREMENT		
Elliott Brothers Ltd.	IW2	Load cells. Various ranges up to 50 tons tension and compression.
	IW3	For weighing crane loads. Ranges as IW2.
	IW4	Electrical weighbridge. Capacities from 800 lb. to 20 tons
	IW5	Electrical weighing system for hoppers, bins and tanks, etc. Ranges as for IW2.

Possible Errors

When stress is present in a direction at right angles to that in which it is being measured, there is a small response of the gauge to this transverse strain. This is known as the cross sensitivity of a gauge, and is a function of grid design. For normal wire-wound gauges this error is in the region

of 1 per cent. The foil strain gauge and the wire grid shown in Fig. 6 have almost zero error from this source.

Care should be taken to avoid exposure of the gauge to draughts, direct sunlight or other effects likely to cause rapid and random changes of temperature. Such random temperature variations produce resistance changes in the gauge and thermoelectric e.m.f.s at each joint involving dissimilar metals, such as where the copper lead wire is soldered to the Advance gauge tag. Both these effects are indistinguishable from strain, but they can be avoided by lagging the gauge from draughts and radiation, and strapping all gauge connections to the base metal.

Cements and Their Correct Uses

The choice of the correct cement and the use of suitable bonding techniques is of major importance, since faults usually become apparent only when the test has been carried out and the results examined. The cement must be free from hysteresis and creep effects; adhesion and electrical insulation must be good; it must be unaffected by changes of temperature and humidity; the drying time must be reasonably short; and it must retain all these properties throughout the full range of strain.

Details of suitable cements and instructions for their use are sometimes supplied by the gauge manufacturer. These instructions should be followed carefully. When no instructions are given, Durofix or Necol 3462 (manufactured by I.C.I.) are quite satisfactory cements for use with paper gauges up to 50 deg. C. For temperatures in excess of this the manufacturer will usually give guidance, but phenolic resins such as Bakelite G11185 or N.P.A. 33127, or epoxy resins such as Araldite X83/27 (made by C.I.B.A. (A.R.L.) Ltd.), have been used successfully at temperatures up to about 200 deg. C.; and above this temperature ceramic cements such as Brimor U527 or U529 (Graphite Products Ltd.) are suitable.

Whatever cement is being used, the following points are worthy of note. They are, of course, supplementary to the manufacturer's instructions, and are in no way intended as alternatives.

1. The surface should be slightly roughened, either by abrasive paper or a light sand blast such as Blastite No. 4 (manufactured by the Carborundum Co. Ltd.).

2. The surface must be absolutely clean and free from grease. After cleaning it should not be handled.

3. Always use tweezers when handling gauges. It is advisable to wash resin-based gauges with a degreasing liquid before affixing.

4. Avoid the use of excess cement.

5. Allow sufficient drying time.

6. When using Durofix or Necol 3462, first apply a thin coat to the metal surface and allow to dry, then apply cement to the back of the gauge and press firmly into position with a rolling motion to squeeze any trapped air and surplus cement from under the gauge. Allow at least 48 hr. drying time. Care should be taken to avoid the presence of moisture.

7. Before using the gauges, they should be checked for continuity, correct resistance and insulation resistance to the metal. If the insulation resistance is below about 50 megohms, the gauge may be warmed slightly by air or radiant heater, but the temperature should not exceed 40 deg. C.

8. If the installation is to be operated in damp conditions the gauges should be waterproofed. Di-jell 171 (Astor Boisselier and Lawrence Ltd.) is a suitable material for short-term operation; but for long-term operation under water, Boscoprene cement 2413 (made by B.B. Chemical Co. Ltd.), Araldite 121 with 25 per cent by weight of thiokol, or even pitch can be used. The Araldite mixture is probably preferable but with all materials care must be taken to ensure complete coverage and adhesion to the leads. Poor insulation resistance is often the cause of zero drift.

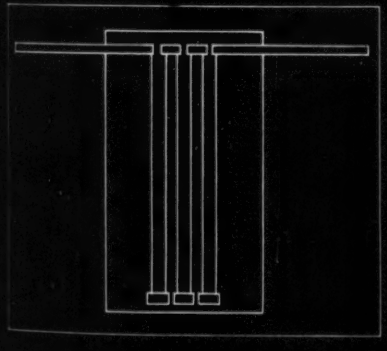


Fig. 6. Low cross-sensitivity gauge.

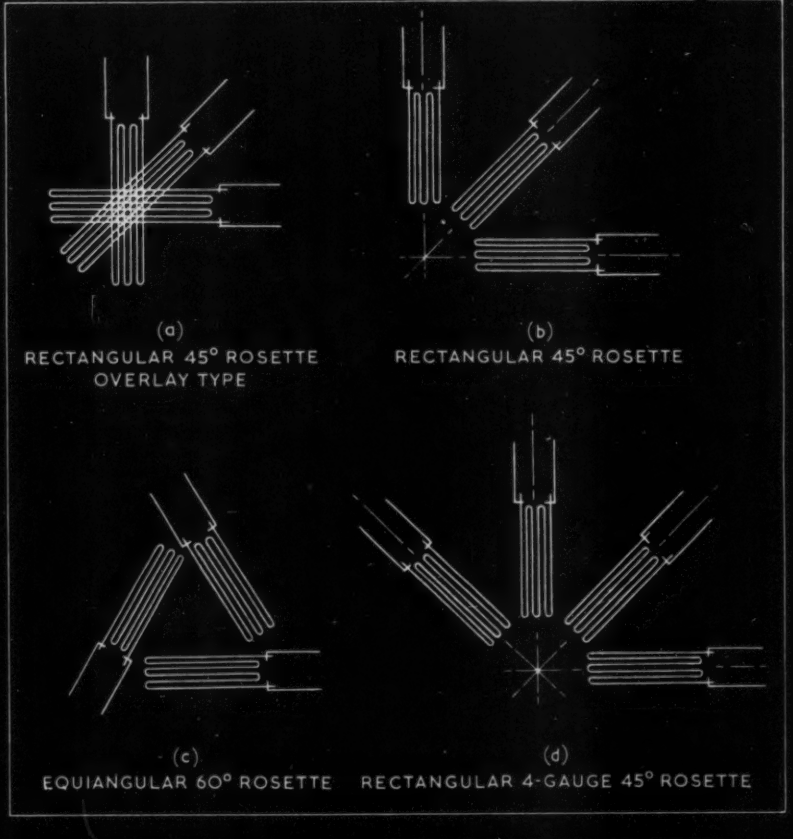


Fig. 7. Types of rosette.

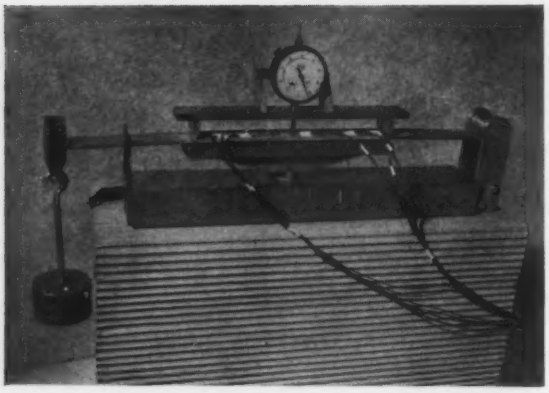


Fig. 8. Circular bending rig for the determination of gauge factor.

Temperature Compensation

The balance of a strain gauge bridge is upset by variations of temperature, since the resistance R changes due to (a) the expansion of the material under the gauge; (b) the expansion of the gauge wire; and (c) the resistance change in the wire due to temperature. The output from the bridge is the algebraic sum of these three effects, and is indistinguishable from the effect of mechanical strain. To overcome this it is necessary to compensate a strain gauge bridge for temperature variations.

In a single active gauge installation, compensation is obtained by using a dummy gauge mounted on an unstrained strip of similar material and placed alongside the active gauge, and in good contact with the base metal. This is used as resistance S in Fig. 3. If temperature variations occur, both R and S will change by the same amount and the bridge will remain balanced.

When equal tensile and compressive stresses are present, as in bending or shear, the gauge S may be affixed directly to the specimen in such a position as to be always strained in the opposite sense to the gauge R. This method gives twice the sensitivity of the single-gauge installation.

When only unidirectional strains are present, compensation is sometimes achieved by fixing gauge S directly to the specimen in a direction perpendicular to the axis of strain. This gives $(1 + \sigma)$ times the sensitivity of the single active gauge installation.

Measurement of Strain and Stress

Paper-based gauges are adequate for the measurement of both static and dynamic strains at room temperature, except where the utmost stability is required, when resin-based gauges should be used. The choice of gauge for a particular job is usually decided by size. The smallest gauges should not be used unless it is essential to do so either on account of available space or the presence of stress gradients, since they cannot be aligned as accurately as longer gauges, and the bond is liable to be inferior.

For the measurement of unidirectional stresses a single gauge is bonded to the surface with its axis parallel to the axis of strain, and the resistance change measured as described earlier. The strain is then calculated using equation (1)

$$e = \frac{\delta R}{KR};$$

or alternatively, since stress $= e \times E$, the stress can be determined directly from the equation

$$f = \frac{E\,\delta R}{KR} \qquad \ldots.(6)$$

When a complex stress system exists, there are present

Table 3. Range of strain gauges available

Huggenberger, Zürich. (British agents—T. C. Howden & Co. Ltd., Leamington Spa.)	A fairly wide range of paper- and plastics-based wire-wound gauges for operation at room temperature. Low cross-sensitivity gauges.
Philips Ltd. (Research & Control Instruments Ltd., London, W.C.1.)	A limited range of wire-wound gauges for use at temperatures up to 200°C.
A. V. Roe & Co. Ltd. (Agents—Armstrong Whitworth Equipment Ltd., Hucclecote, Gloucester.)	A wide range of wire-wound gauges. Paper-based gauges for use at room temperature. Araldite-based gauges for use up to 200°C. Ceramic-based gauges for use up to 750°C. Gauges supplied on frames for attachment by the Rokide process (Norton Grinding Wheel Co., Welwyn Garden City, Herts.) Special gauges to customers' requirements. High-temperature gauges can incorporate built-in thermocouples for temperature monitoring and bridge compensation, if required. Low cross-sensitivity gauges.
Rotol Ltd., Gloucester.	A fairly wide range of wire-wound gauges. The J type resin gauges for use up to 200°C. The D type cellulose gauges for use up to 60°C.
Saunders-Roe Ltd., East Cowes, I.O.W.	A fairly wide range of foil strain gauges. Linear gauges for use up to 100, 300 or 800°C. Torque and rosette gauges for use up to 100 and 300°C. Diaphragm gauges for use up to 100°C.
Technograph Electronic Products Ltd., London.	A limited range of foil strain gauges. Type 1—general-purpose linear gauge for use up to 200°C. 4- and 6-in. linear gauges for use around room temperature. Torsion sensitive gauges for use up to 170°C.
Teddington Industrial Equipment Ltd., Sunbury on Thames, Middlesex.	A wide range of paper-backed gauges for use up to 110°C.
H. Tinsley & Co. Ltd., South Norwood, London, S.E.25.	A wide range of wire-wound, and some foil strain gauges. Wire-wound paper-base gauges for use at room temperature. Araldite gauges for use up to 80°C. Bakelite gauges for use up to 250°C. Medium-temperature gauges for use up to 300°C. High-temperature gauges for use up to 800°C. High-resistance foil gauges for use at room and elevated temperatures.

Table 4. Strain measuring and recording equipment

Armstrong Whitworth Equipment Ltd.	D.c. amplifiers and attenuators. High-speed switching devices, and miniature spot welders for lead attachment. Special equipment and installations to customers' requirements.
Brüel & Kjaer, London.	Portable static and dynamic strain measuring equipment.
Huggenberger, Zürich.	Portable strain indicator for static and dynamic work.
New Electronic Products Ltd., London.	Galvanometer photographic and ultra-violet recorders. A wide range of galvanometers—carrier amplifiers.
Philips Ltd.	A range of direct indicating strain measuring bridges. Cathode ray oscilloscopes and cameras. Four-channel oscilloscript recorder.
Savage & Parsons Ltd.	Static and dynamic measuring equipment.
Southern Instruments Ltd.	Strain measuring unit for static and dynamic work. D.c. amplifiers and pre-amplifiers.
H. Tinsley & Co. Ltd.	Static and dynamic strain measuring equipment.

two mutually perpendicular planes on which only normal stresses exist. These are known as principal planes and principal stresses respectively, and it is the magnitude and direction of these stresses that are usually required to be measured. If the directions of the principal stresses are known, their magnitude can be determined from two mutually perpendicular gauges placed along the directions of principal stress. The principal strains are given directly as

$$e_x = \frac{\delta R_x}{K R_x} \qquad \ldots.(7)$$

$$\text{and } e_y = \frac{\delta R_y}{K R_y} \qquad \ldots.(8)$$

The principal stresses are then computed directly from the relationships

$$X = \frac{E}{1-\sigma^2}(e_x + \sigma e_y) \qquad \ldots(9)$$

$$\text{and } Y = \frac{E}{1-\sigma^2}(e_y + \sigma e_x) \qquad \ldots.(10)$$

When the directions of the principal stresses are not known, three gauges must be used. These are usually arranged in the form of a 45° rosette, as in Fig. 7, a and b. From the measured strains e_1, e_2 and e_3, the direction of the maximum principal stress relative to e_1 is given by

$$\tan 2\theta = \frac{2e_2 - e_1 - e_3}{e_1 - e_3} \qquad \ldots.(11)$$

Numerator	Denominator	2θ
+	+	0 – 90°
+	–	90 – 180°
–	–	180 – 270°
–	+	270 – 360°

The angle θ is not completely defined by the sign of the tangent. The correct value can be determined from the sign of the numerator and denominator as given in Table 5. The principal strains are computed from the following relationships:

$$e_x = \frac{e_1 + e_3}{2} + \sqrt{\tfrac{1}{2}[(e_1 - e_2)^2 + (e_2 - e_3)^2]} \qquad \ldots.(12)$$

$$\text{and } e_y = \frac{e_1 + e_3}{2} - \sqrt{\tfrac{1}{2}[(e_1 - e_2)^2 + (e_2 - e_3)^2]} \qquad \ldots.(13)$$

from which the principal stresses can be determined using equations (9) and (10).

The relative formulæ for the other rosette configurations are included in Table 1.

A rosette can be manufactured either as one unit or made from separate gauges. In the latter case the gauges should be grouped close to the point at which the stresses are to be measured, and fairly small gauges should be used. The overlay type of rosette is perhaps the most commonly used.

Calibration of Strain Gauges

The gauge factor of each production batch of gauges is determined by the manufacturer, and the value is quoted on each package. The check is usually carried out by mounting a sample quantity of gauges on to a beam which can be strained in a circular bending apparatus as shown in Fig. 8. The applied strain is calculated from the simple bending theory, and the change of resistance measured on a Wheatstone bridge, thus giving the gauge factor directly as

$$K = \frac{\delta R}{eR}.$$

During automatic recording, calibration is effected by introducing a known change of resistance into the bridge by switching a high resistance in parallel with one of the fixed arms, as shown in Fig. 3. The signal is introduced and recorded at frequent intervals as a consistency check on the recording apparatus.

When gauges are to be used for load measurement, as in load cells or weighing machines, calibration is most accurately determined by loading the unit statically in a hydraulic or deadweight testing machine.

Uses of Strain Gauges

The versatility of the strain gauge makes it impossible to mention all its uses. Most gauges are used to determine working stresses in large structures, but many are also used for detail work such as the measurement of torque in rotating shafts, and the determination of stresses and resonant frequencies in turbine blades. The aircraft industry is perhaps the biggest user of strain gauges in these respects, due to the necessity for a comprehensive stress analysis of structures, both statically and dynamically. Ever-increasing numbers of gauges are, however, being used in civil, nuclear and other branches of engineering, in the design of bridges, reinforced concrete structures, reactor pressure vessels, fuel elements, etc. New uses are constantly being found, and it is doubtful if any branch of engineering could not use more strain gauges to advantage.

A large number of strain gauges are also used as sensing elements in instruments developed for the measurement of acceleration, amplitude, pressure, load, weight, etc. Some of these devices are listed in Table 2.

Accuracy of Results

To obtain the greatest accuracy in results, a careful watch must be kept for possible sources of error at all

stages of the investigation. When planning a test, due attention should be given to positioning of the gauges. Haphazard positioning on complex structures often leads to the maximum stresses being missed. The problem can best be overcome by the use of brittle lacquer as a qualitative test to determine the highly stressed regions where gauges should be affixed. If compressive stresses are likely to be present in thin components, gauges should be placed on either side of the component and wired in series to remove bending effects due to buckling.

When wiring an installation, a good standard of electrical practice and a high level of instrument maintenance should be maintained. All joints should be soldered and attention given to plug and socket connections, as poor contact here leads to instability in the whole installation.

The use of thick waterproofing coats on thin specimens and operation under high hydrostatic pressures is likely to affect gauge sensitivity and calibrations, and relevant precautions should be observed.

In dynamic work the measuring equipment should be capable of responding correctly at the frequencies involved. This affects mainly the use of amplifiers and galvanometers. When measuring impact loads, a high frequency oscillograph should be used in conjunction with a camera.

Subject to suitable care being taken, the results from a static test should be accurate to within ± 5 per cent, and for dynamic work the possible error should not exceed ± 10 per cent, although this can be considerably improved by calibration.

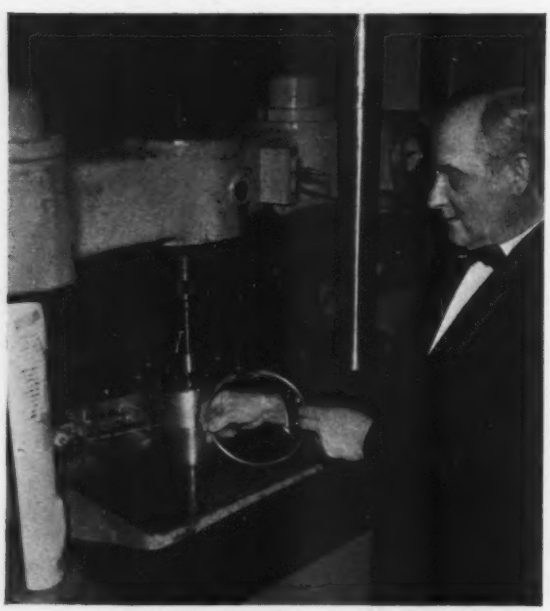
Fig. 9. Typical strain gauge installation, partly waterproofed.

The author wishes to thank the directors of A. V. Roe & Co. Ltd. for permission to publish this paper, and for providing the photographs reproduced therein.

TENSILE TESTER FOR GLASS FIBRE

LIGHTWEIGHT glass fibre rocket motor chambers reinforced with non-woven glass fibres (roving) seem to be destined soon to become standard equipment for space vehicles. Chambers of this description may cost only a fourth as much, and be up to three times as strong on a weight basis, as metal chambers at present in use. This prediction comes from chemists at the Naval Ordnance Laboratory in Silver Spring, Maryland, U.S.A., who have developed a test device for studying glass fibre. This development is part of an NOL programme to evaluate parallel glass fibres as reinforcement for plastics pressure vessels, e.g. rocket motor chambers.

NOL chemist Dr. Erickson examines a parallel glass fibre reinforced plastics ring which he has just ruptured with the hydraulic ring tensile tester.



Called the "NOL Hydraulic Ring Tensile Tester", the new test device is being used to obtain quality control data needed to define more precisely the strength and environmental resistance properties of parallel glass filament for reinforcing plastics. These data will ultimately be used in specifications for glass roving for reinforcing plastics.

Essentially, the tensile tester is a pressure-tight housing in which glass fibre test hoops are hydraulically ruptured. Data collected with the tester in this manner are used to determine the hoops' tensile strength and modulus of elasticity. In many cases, these data are directly applicable to the design of large rocket motor chambers, since the test hoops and the chambers are similar in shape.

Known as "NOL Rings", the test hoops were specially designed at the Naval Ordnance Laboratory for tensile tests. They are fabricated by drawing glass strands through a resin bath on to a circular mould under controlled conditions of temperature, tension and angle of wind. Tests so far conducted with the rings have indicated that the application of a chemical finish to glass fibres is one of the important factors in improving the tensile strength of a glass reinforced plastics.

Parallel glass fibre reinforced plastics have achieved widespread scientific interest during the past few years for reasons other than the material's attractive strength-to-weight ratio. Plastics reinforced in this manner offer the engineer a means of controlling the directional strength of a structural item to a degree not possible with woven fabric or random mat glass fibre. Also, parallel glass fibres can theoretically be packed to occupy over 90 per cent of the volume in a reinforced plastics. This is a definite advantage over mat glass fibre, because the strength properties of a reinforced plastics are directly proportional to the glass content.

"In view of the extent of structural development work already done, the development of quality control techniques and specifications for glass roving to be used in pressure vessels is most timely and long overdue," said Dr. Porter W. Erickson. Dr. Erickson shares credit for development of the tester with F. Robert Barnet, H. A. Perry, Hyman Kessler and Virgil Milani, of the non-metallic materials division of NOL's chemistry research department.

LETTERS TO THE EDITOR

Burnishing of Holes

Sir,

In the January issue (page 8) you give an outline of a process for the internal burnishing and sizing of holes. We wish to call your attention to the fact that this method is not new to this company, who have, for the past thirty-five years, extensively advertised a process known in the gun trade as "ball burnishing". In this period many thousands of 0·303 in. calibre service rifle barrels have been so treated.

The advantages claimed by us for the ball burnishing process are as follows: (1) the removal of very fine tool marks left in the bore even after fine boring and lapping (these collect particles of nickel from the bullet and destroy accuracy); (2) improvement of parallelism of the bore; (3) the work-hardened and polished surface so formed on the "lands" gives longer life to the barrel, by increasing the resistance of the "lands" to bullet wear.

The accuracy of the modern rifle over long ranges, and the years over which this company has been using this method of ball burnishing with success, enable us to endorse the statements in your article, but, as you see, the method is not new.

A. H. Cleaver

Parker-Hale Ltd.,
Bisley Works,
Whittall Street,
Birmingham, 4.

Outlook on Design

Sir,

To get to the root of the design question, it seems necessary to consider the past as well as the present in order to see the matter in true perspective. For example, one may recall the outstanding position of Britain from the beginning of the industrial era to World War I, a period of about 150 years which included the great pioneers Watt (steam engines), Faraday (electricity), Stephenson (railways), Ackroyd (oil engines) and Parsons (turbines).

If we have not done as well in the following period of forty-five years to date, what is the reason? Two outstanding events come to mind: the two World Wars, which have resulted in serious gaps in available personnel of suitable calibre for design work; and the shrinking value of sterling, whereby the control of big business has largely passed from pioneers to financiers and the Government. This last may be a good thing in the course of time, because everything tends to become larger and more complicated, which adds greatly to the work of designers, while at the same time financial and commercial affairs demand greater knowledge and experience.

It has been asked: "Are we spending enough on design?" The answer might well be: "Yes—but too much on experimental apparatus and too little on actual design!" For it has been said: "The most important instrument in research is the human mind." And this is supported by history and by our success in the pioneering days, when we had of course very little experimental apparatus but did better. So the question arises: "Are we using our present wealth of testing plant to the best advantage?" The answer is, first, the need for definite concepts from scientists and designers to put to practical tests—only then can the cost of the apparatus be fully justified.

The terms "scientist" and "designer" are now bandied about very loosely—a lot depends upon what we really mean by "design". Do we refer to *original* work with a view to progress, suiting some special purpose and competition in world markets? Or do we mean just *copying* what has already been done, perhaps with larger dimensions and minor modifications. The primary need today is action directed to finding real design talent comparable with that of the great designers of the past. Have we perhaps relied too much upon our inheritance, and thought too little of grasping the torch handed to us, and going on from there? Would it not help to put the emphasis on *original* work as part of the normal duties of the employee, instead of making him hand over his rights with regard to his inventions as a condition of employment?

Much has been accomplished by intensive production methods, but has our recent outlook been sufficiently advanced to ensure progress in design commensurate with the highly developed manufacturing techniques? There seem to be instances of failure to appreciate the importance and extent of a designer's work, and of course it is always easier to make a thing than to design it!

In the old days the designer was frequently the owner of the business, and if he made a mistake and paid for it, learned from it, and "lived to fight another day". When he succeeded, he automatically received a reward. In these days, if a designer makes a mistake it may mean the loss of his job, but in success little or no encouragement is given to "burn midnight oil" in an endeavour to succeed again.

It seems reasonable to conclude that any "new outlook" on design should recognise the importance of design in all grades, in order to obtain maximum effectiveness from a minimum of material and work, and the optimum performance from the product. This is not intended to refer to fair emoluments for any class of work, but to encourage men of the right calibre for design work, who are generally more interested in design than in money. However, design work being of a kind which demands special concentration, these men do need freedom from money worries; and the new outlook should take into account the fact that their most valuable work is more likely to be done in the middle of the night rather than in the office.

As to the "training of designers", "original thinking" cannot be learned from school books, which can treat only of the past—design consists of looking into the future, not backwards. Design is an art, for which there must be initial aptitude—talent—to be developed. Such development can only be assisted(!) by those who have already succeeded in the particular art in question, who can inspire a habit of looking forwardly.

The method formerly used in engineering design was, after the new entry had been educated and grounded in scientific subjects and had served an apprenticeship in practical work, if he then showed promise he was given the opportunity to become a pupil in a design office, directly under an eminent designer, for a period of years—something like a budding artist working directly under an eminent painter.

In engineering, practical experience is very necessary, to avoid repetition of past mistakes, as also is up-to-date knowledge of current developments. This suggests that many older men might be recalled, since the body (unless showing signs of senile decay) is no criterion of a man's mental abilities. Many of the greatest scientists and designers did momentous work in their old age. In any case, the man who has succeeded in the past is likely to succeed again.

It must always remain that "originality" is rare, and cannot be learned—if it could, it would not be rare.

F. Gordon Pratt

35 Petersham Road,
Richmond,
Surrey.

Jet Thrust Indicator

Sir,

With reference to the article on a jet thrust indicator appearing under "New Ideas in Design" of your March issue, we wish to inform you that we are the associate company of Industrial Acoustics Co. Inc., of New York.

At present the jet thrust indicator is undergoing rigorous test-stand and in-flight evaluation testing which it is hoped will be satisfactorily completed during the course of the next three months. Tests to date show that the unit functions satisfactorily, but it is our desire to complete an extended testing programme before making the unit available on a guarantee basis.

In addition to the jet thrust indicator, we are designers and fabricators of all types of noise-reducing equipment, particularly for jet engines. Several of our lightweight multi-jets have been purchased, for use in the U.K. and on the continent, including a repeat order for six trailer-mounted multi-jets.

V. Singleton

(Technical Manager)
Industrial Acoustics Co. Ltd.,
Victor House,
Norris Road,
High Street,
Staines,
Middlesex.

DEVELOPMENTS IN VACUUM CONTACT DEHYDRATION

An accelerated freeze drying process developed in Denmark has proved to be of great value as an improved method of preserving food, especially in view of its commercial adaptability

by Dr. Tech. ETTRUP PETERSEN, B.Comm.Sc.*

IN 1942 extensive research was initiated in the Atlas laboratories, in Copenhagen, on the factors determining the retention of the important biological factors, and also of the taste and smell, in foodstuffs during dehydration and storage. It was proved that the various enzymes, principally oxidases, were active during the drying process, especially when this was carried out as air drying, but that during storage the enzyme activity was unimportant in proportion to the influence of the water content of the dried material.

It was discovered that, by initial heat treatment, or by the use of chemical agents to inactivate the enzymes, improvements in the quality of the dried products could be obtained. However, fully satisfactory products were not obtainable through air drying even in this way, and new procedures had therefore to be developed.

* Member of the Danish Engineers' Association.

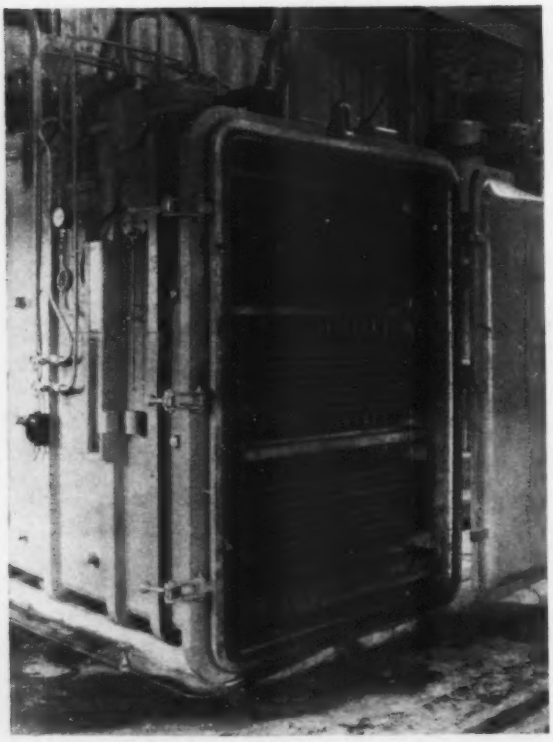


Fig. 1. The first commercial vacuum contact drying plant, used mainly for drying codfish.

During storage tests it was found that vitamin C was oxidised at a rate which was proportional to the square of the water content, and that therefore this content had to be extremely low, i.e., a maximum of 3-4 per cent. A water content of this order was difficult to obtain through air drying, and it was obvious that this method had to be replaced by a process in which the water could be removed practically completely in the absence of oxygen.

The obvious answer to the above questions was drying in vacuum, and experiments with this process were therefore initiated in 1943. However, it was soon found that a number of difficulties had to be overcome before an economically satisfactory procedure could be reached.

The main obstacle in vacuum drying is that the drying time is essentially longer than that for air drying, due to the fact that no heat transfer medium is available. The calories necessary for the evaporation must therefore be transmitted through contact with a heated surface, through radiation or through high-frequency heating. These three possibilities were all investigated, and radiant heating was soon given up due to the fact that the thermal conductivity of an outer layer of fully or partly dried material was too low to prevent a build-up of high temperatures, before the evaporation in the inner parts of the drying goods could absorb the heat generated. Discoloration and scorching resulted, and the products were rendered useless.

High-frequency heating is apparently a very good way of applying heat to a material being dried under vacuum, as the energy absorbed is directly proportional to the dielectric constant of the matter exposed. As this constant for water is much higher than that of carbohydrates or protein, this is a selective way of heating, and the calories transferred are concentrated mostly in the moist parts of the drying goods, which is desirable. However, two reasons speak strongly and decisively against high-frequency heating. The first is that the efficiency of the generators is too low to permit economic operation, and the second is that the conductivity of the air at high vacuum is sufficient to permit corona formation, resulting in the material being scorched.

The only possibility left after this was heat transfer by contact between the drying material and a heated surface, and this apparently simple method also presented difficulties. It is well known that dried foodstuffs like vegetables, fish or meat have a very low thermal conductivity, due to the fact that they are very porous. As the heat will have to penetrate from the outside, the outer layers will dehydrate first, and thereafter make an efficient barrier preventing

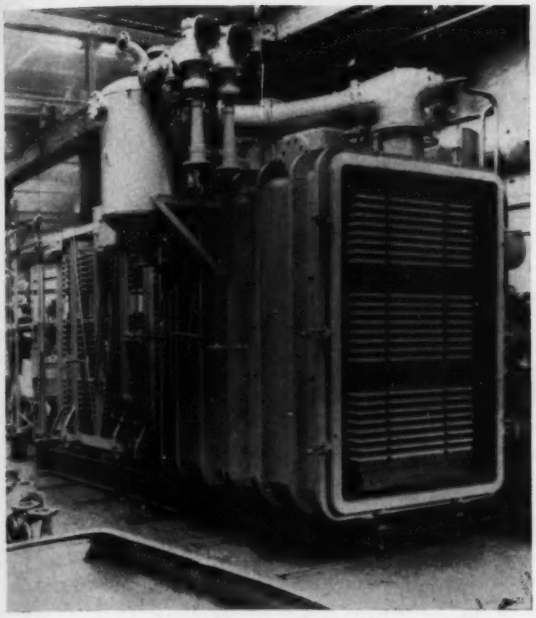


Fig. 2. More advanced type of plant, incorporating an improved vacuum system.

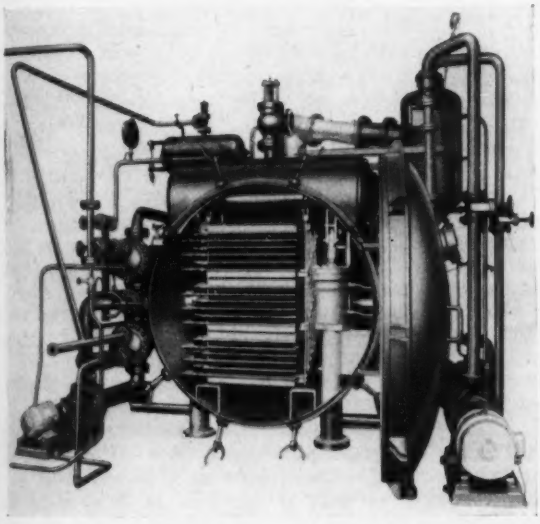


Fig. 3. Showing the basic layout of the improved system, with which freeze drying is possible.

penetration of heat to the inner layer of the drying material, thus prolonging the drying considerably. Another difficulty is that many foodstuffs, when placed on a flat tray, have relatively few contact points with the surface, and an even transfer of heat to the bulk of the material is therefore hampered.

In order to overcome these difficulties, attempts were made to press the material against the heating surface during drying, and by this procedure considerable improvements in heat transfer were arrived at. Even better results were obtained by placing the material between two heating plates which could be moved towards each other, thereby exerting a pressure on the material to be dried. Using this method, it was found that the drying time of a 25 mm. fish fillet could be reduced to about 6 hr., as against 16-18 hr. by one-sided contact without pressure.

When drying certain materials, such as spinach, it was observed that the material collapsed to such an extent that the vapour could not escape to the condenser, but this was efficiently counteracted by the insertion of wire netting between the trays and the drying material, providing adequate escape routes for the vapour.

First Commercial Plant

In 1946 the first commercial vacuum contact drying plant was established in Aalesund, Norway, principally for the drying of fresh and salted codfish. This plant (shown in Fig. 1) consisted of a cabinet which could be evacuated by means of a water jet ejector to about 25 Torr.

Twenty-four heating plates, each 2·5 × 1·20 m., were arranged in three sections and independently suspended in moving bars so that the spacing between the individual plates could be varied between 35 and 10 mm. The plates were completely counter-balanced, so that the distance between any two plates in a section was always the same. The moving bars were actuated by upper levers, which were operated hydraulically in such a way that a controlled pressure varying from zero to 5,000 kg./sq. m. could be exerted on the drying goods.

The heating was carried out by means of hot water circulated through the multi-labyrinth plates, to provide temperatures varying from 20 to 140 deg. C. The raw material was placed on aluminium trays, which were then placed in a rack car from which they could be pushed into the cabinet and between the heating plates in one operation. After closing the front door, the vacuum was applied and the heating started. The vapour given off was condensed in a spray condenser by means of sea water. The results achieved confirmed the laboratory experiments, as drying times of 6 hr. for fish fillets were readily obtained.

Even though the quality of the products was acceptable, the company operating the plant could not obtain sufficient financial backing, and operations therefore came to a stop in 1948. However, the process had created interest in other circles, and an official British delegation searching Europe for new food handling processes declared that this was the most important development they had spotted. In the meantime, research was carried on in the Atlas laboratories, and it was found that by increasing the vacuum the quality of the products could be improved, even if the drying times could not be diminished, and a pilot plant furnished with steam ejector, condenser and vacuum pump was tested.

When, in 1950, a plant was delivered to the experimental factory of the British Ministry of Food, situated in Aberdeen, this system was incorporated, as can be seen from Fig. 2. The basic construction of this cabinet was the same as that of the Aalesund one, but the vacuum system consisted of a steam jet ejector, a spray condenser and two water jet ejectors. During the preliminary tests of this plant it was found that vacua of the order of 2·5 Torr. could be obtained, so it was possible to freeze the raw material before the drying and, if the sea water was very cold, and the load on the condenser small, vacua of even 1 Torr. could be reached. This initiated freeze drying.

In several plants delivered in the following years the same type of vacuum plant has been adopted, as can be seen from Fig. 3. In order to avoid the heavy stationary equipment for loading and unloading the trays, the size of the cabinet has been reduced, so that eighteen heating plates of 1·50 × 0·75 m. surface have become available for the process. Furthermore, the cabinet has been given cylindrical shape, as this is of course the ideal design for withstanding the heavy outside air pressure during evacuation. In addition, the solution to the packing problems of the front door are greatly facilitated by the cylindrical shape.

A cabinet of this type, installed for Aerated Foods Ltd. in their Aberdeen factory in 1955, has been working constantly on the freeze drying of various foodstuffs, and considerable experience has been gained.

P.v.c. control cables (by British Insulated Callender's Cables Ltd.) at the rear of the Steel, Peech & Tozer Ltd. steel-finishing mill control board, at Brimsworth, Sheffield.

RUBBERS AND PLASTICS IN CABLES

A joint conference of the Plastics Institute and the Institution of the Rubber Industry was held at the Institution of Electrical Engineers, in London, on March 1—the papers presented are summarised

THE following synopses are given for general information only, since each paper is to be published in full in either the *Transactions of the Institution of the Rubber Industry* or in the *Plastics Institute Transactions*.

The Problems of Electricity Transmission, by Sir Christopher Hinton, K.B.E., F.R.S. (Central Electricity Generating Board). For transmission outside urban areas, amenity apart, cables are rarely preferable to bare overhead conductors. The Generating Board uses hardly any cables; the Area Boards use cables for virtually all their distribution within urban areas. The main objection to undergrounding is cost. An underground 275 kV. cable costs seventeen times as much as an overhead line of equal capacity; three-eighths of the cost is accounted for by civil engineering work. The Generating Board are considering undergrounding in special cases. There is need to develop reliable cables for 275 kV. or higher voltages. A fundamental difficulty with a.c. transmission is the necessarily high capacitance of the cable. The Board have studied the use of d.c. transmission, including underwater transmission links, in the interests of amenity, but the cost is prohibitive. A large reduction in the overall cost of undergrounding low-voltage cables is necessary. It is important to develop a flexible, compact, quickly jointed cable that can be laid across country by a continuously operated machine. This calls for integrated research by cable experts and civil and mechanical engineers.

The Electrical Properties of Polymeric Insulating Materials in Power Cables, by N. Parkman, B.Sc. (Electrical Research Association Laboratory). This paper reviews cable requirements and associated demands on the properties of dielectric materials, low-field phenomena, high-field phenomena and the intrinsic and practical electric strengths of polymers, including thermal breakdown and breakdown by discharges in polymeric dielectrics. Examples are given of advantages and limitations of modern plastics and rubbers as cable insulation.

Use and Performance of Trailing Cables in Mining, by W. C. Wymes (National Coal Board). The types of trailing cable in common use for coal cutting machines, portable drilling machines, conveyors, etc., are reviewed. Reference is made to the pending extension in the utilisation voltage at the coal face and the adoption of a restricted fault current system of earth leakage protection, and the effect these may have on trailing cable design. Semi-conductive elastomers are considered as possible replacements for metallic earth screens. The use of p.v.c. insulated and sheathed cable for power distribution purposes is discussed.

Stabilisation of Plastic Insulating Materials for Wire and Cable, by W. L. Hawkins, M.S., Ph.D., and F. H. Winslow, M.S., Ph.D. (Bell Telephone Laboratories Inc., U.S.A.). Plastics insulating materials exposed to natural weathering must be protected against both photo- and thermal oxidation. It has been found that carbon black, which is normally used as a light screen, may also inhibit thermal oxidation. The inhibiting properties of this material are attributed to the presence of oxygen- or sulphur-containing groups on the particle surface, since increasing the concentration of these reactive groups considerably improves the anti-oxidant effectiveness of the pigment.

Carbon black and a variety of sulphur compounds form anti-oxidant combinations which inhibit polymer oxidation to a much greater extent than anticipated from the contribution of the individual components. Formation of these anti-oxidant combinations is apparently independent of surface reactivity, since carbons, essentially free of reactive groups, also form synergistic combinations. Organic compounds which function similarly to carbon black with sulphur compounds have been developed. These compounds are related structurally to carbon black, and a mechanism was suggested by which these synergistic anti-oxidant combinations could function.

Telecommunications, with Particular Reference to Cables and Their Requirements, by R. J. Halsey, C.M.G., B.Sc., F.C.G.I., D.I.C., M.I.E.E. (Post Office Engineering Department). An outline is given of the pattern of modern telecommunication systems, internal, international and global, and of the trends of future developments. Cables, of dif-

ferent types and having widely varying requirements, are essential features of nearly every link in the complex network which must provide telephone, telex, music and television facilities. Domestic networks must be sufficiently good to allow of connections to other countries where similar networks will be encountered. Inter-continental circuits, until recently all radio, are now being replaced and supplemented by ocean cables, providing better and more reliable service. Cables of all types require both insulation and protection from external influences to which they are exposed; rubbers and plastics have important and sometimes exclusive roles in relation to both these requirements.

Recent Devlopments in the Use of Neoprene for Wire and Cable, by K. H. Whitlock, B.Sc. (Du Pont Co. (United Kingdom) Ltd.). The service history of neoprene in the cable industry is reviewed, and recent developments associated with processing and compounding for specific purposes —e.g. tear resistance, ozone resistance, heat resistance, improvement in electrical characteristics, low-temperature resistance and the use of neoprene types W-Ml and WHV— are discussed.

The Use of Fluorinated Elastomers in Cables, by K. H. Whitlock, B.Sc. (Du Pont Co. (United Kingdom) Ltd.). The general processing and physical and electrical properties of typical Viton formulations are reviewed, and some suggestions made for possible wire and cable applications.

Nitrile Rubber and Vinyl Polymer Mixtures, by C. Y. Almond, M.A., Ph.D., F.R.I.C. (Imperial Chemical Industries Ltd.). The outstanding resistance to abrasion, oil, fire and ozone of vulcanised nitrile rubber/p.v.c. blends has stimulated cable manufacturers throughout the world. In this paper the effect of polymer properties on mixing conditions is discussed, and the physical properties resulting from different mixing conditions reviewed. The physical (including electrical) properties of vulcanised and unvulcanised nitrile rubber/p.v.c. blends are related to the use of these blends in covering electric cables. Comparisons are made with other types of sheathing and insulating materials, and both existing and potential uses of nitrile rubber/p.v.c. blends in cable covering are discussed.

The Basis and Practice of Compounding Butyl Rubber for Cable Insulation, by A. G. Strong, M.Sc. (Esso Petroleum Co. Ltd.). Despite the apparent suitability of butyl rubber as an insulating material, its general adoption has been slow, and only recently has its use been extended. The reason for this lies in the balance of polymer properties which, while favouring service performance, can prejudice compounding and processibility. For cable insulation the basic polymer features of butyl are composition, molecular size and shape, cross-linking and response to degradation. Studies of these factors with particular reference to polymer-filler interaction, accelerator function and cross-link stability have allowed the modification of certain properties without detraction from other desirable characteristics. These developments, which have led to the introduction of new compounding ingredients and new processing techniques, are described together with their application in the manufacture of high- and low- voltage butyl cables.

Irradiation of Polymeric Materials, by R. M. Black, M.Sc., Ph.D., A.R.I.C. (British Insulated Callender's Cables Ltd.). The irradiation of polymeric materials is becoming of increasing interest to the cable technologist, not only with the object of obtaining design data for insulation for use in nuclear reactor applications, but also as a technique for the modification of dielectric materials by radiation-induced cross-linking and graft copolymer formation to give improved or potentially interesting products.

The criteria for the use of insulation in nuclear environments are discussed. The chief limitations are operating temperature, and resistance to the effects of radiation, and with organic polymers, maximum tolerable radiation dose would appear to be of the order of 5×10^8 rad., with a maximum operating temperature of 100-150 deg. C. A pilot-scale plant for radiation processing is described, and an account given of some of the recent applications of irradiated polymers.

WELDING ROLLER FOR PLASTICS FOIL

RECENT developments in industry have resulted in a considerable demand for articles made of plastics foil. In making this foil into articles, the most significant property is the weldability of each type. In particular it is necessary to know the possibilities and limitations of the machines or devices used to weld the foil. The welding unit consists of a control with connections for 220 V. mains (a.c.), and a welding roller attached to the control unit by a cable. A graduated control of the unit makes it possible to adapt the welding current to the type of foil and its thickness, or to the welding rate. When this machine is used for simple manual roller welding of plastics foil, seams of differing length and position can be produced (straight, curved, external or internal, simple or folded, and contoured), as required in various protective and display coverings for widely varying purposes, e.g., for protection against damage, dirt, dust, drying and moisture (rust protection), as well as against other physical, chemical and bacteriological effects.

Apart from the many uses of the unit, it is noteworthy that by fitting the roller with separate handgrips it can be made into a multi-purpose roller with extensive applications for special jobs, for example the production of seams of varying width, single-sided or double-sided welding, twin welding, ornamental welding or signature welding. The contact rings of the welding rollers are usually coated with a special anti-adherence layer. The unit can be used to weld polyethylene foil up to a maximum of 0·2 mm. P.v.c. foil, polyamide, shrunk film and laminated foils can also be welded.

The following data on the welding of polyethylene foil will serve as a general guide, although it is recommended that welding tests be carried out in every case.

Foil Thickness (mm.)	*Welding Current* (A.)	*Welding Rate* (mm./sec.)
0·05	16	80
0·1	18	80
0·15	22	80
0·2	24	70

The fields in which the roller welding of plastics foil is used include: tropical-proof packing of machines and spares of all types; production of protective hoods and covers up to the largest possible dimensions, e.g., for aircraft; manufacture of rainwear, and other articles of clothing having moisture-proof properties; welding of structural and cover foil for plant culture; sealing of valuable documents in museums (as in the Deutsches Museum, Munich); sealing of confidential or secret letters, etc., in the diplomatic service (here a signature ring is used to guard against tampering); adhesion of plastics to paper, or paper to paper; and in packaging machines.

Contributed by F. Weisser, Gebruder Holtschmidt G.m.b.H., Augsburg.

THE INDUCTION-TYPE FREQUENCY CHANGER

This article describes an economical method of increasing supply frequency by means of a frequency changer, with the object of extending the speed range of the industrial motor

by P. B. GREENWOOD, B.Sc., A.M.I.E.E.

THE plain squirrel-cage induction motor is the simplest and cheapest type of electric motor available—hence its great popularity. It suffers, however, from certain limitations, chief of which is that it is essentially a constant-speed machine. Its running speed over the normal load range is generally within 5 per cent below the speed of its rotating magnetic field (or "synchronous speed").

Furthermore, the choice of "synchronous speeds" available to the potential user is limited by the supply frequency. Thus on a 50-c/s supply the synchronous speeds available are as follows:

No. of poles—	2	4	6	8
Syn. speed (r.p.m.)—	3,000	1,500	1,000	750
No. of poles—	10	12	14	16
Syn. speed (r.p.m.)—	600	500	428	375

Since the number of poles cannot be less than a pair, it is impossible to obtain speeds higher than 3,000 r.p.m., using plain induction motors on a 50-c/s supply. Obviously, any economical method of increasing the supply frequency presents a method of extending the range of the induction motor. This is done by the use of a frequency changer, whereby speeds as high as 24,000 r.p.m. can be obtained. One or more high-speed motors can be run from one changer, according to size.

Principle of Operation

In a slip ring induction motor, the frequency of the rotor currents and the voltage induced in each rotor phase are both proportional to the difference between the speed of the rotating field and the speed at which the rotor is turning. In other words, the voltage and frequency appearing at the slip rings are proportional to each other, and are both functions of the motor speed. Thus, if its rotor is separately driven by, say, a cage motor, the slip ring machine functions as a frequency converter, and is in fact the simplest and most efficient type that is known.

It can be driven at a fixed speed, to give constant frequency output, or at a variable speed, if variable output frequency is desired. In the latter case, the output voltage varies in proportion to the frequency, a characteristic which is ideal for supplying power to rotating machinery. Frequencies within the range 500 c/s down to about 16·6 c/s are possible (though not usually from the same machine).

If n_1 is the driven speed, n_2 the synchronous speed of the changer field and f_1 the supply frequency, then the output frequency f_2 is given by:

$$f_2 = \frac{n_1 \pm n_2}{n_2} \times f_1$$

now $n_2 = f_1 \times \frac{60}{p_2}$ where p_2 = number of pairs of poles,

$$\therefore f_2 = \frac{n_1 p_2}{60} \pm f_1$$

The plus sign represents field rotation in the opposite direction to the drive, and the negative sign rotation in the same direction as the drive. Thus two output frequencies are available at any one driven speed. The above relationships are illustrated graphically in Fig. 2.

Selecting the Number of Poles

With frequency changers, as with induction motors, it is good economics to select a machine with the least practicable number of poles, as maximum efficiency and minimum physical dimensions are thereby obtained. However, it will be noted from the above formula that the fewer the number of pole pairs p_2, the greater must be the driven speed n_1 to obtain a given output frequency. Since n_1 must generally be limited to 3,000 r.p.m. (or lower in large changer sets), this often fixes a lower limit to the number of poles.

For example, a frequency changer providing 400-c/s output from a 50-c/s supply would require at least fourteen poles (seven pairs) in order to limit the driven speed to 3,000 r.p.m., as follows:

$$f_2 = \frac{3{,}000 \times 7}{60} \pm 50 = 400 \text{ or } 300 \text{ c/s.}$$

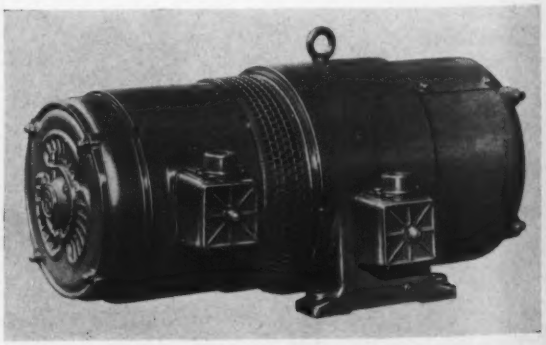


Fig. 1. 3-kVA. 400-c/s changer set on a common shaft. (Brook Motors Ltd.)

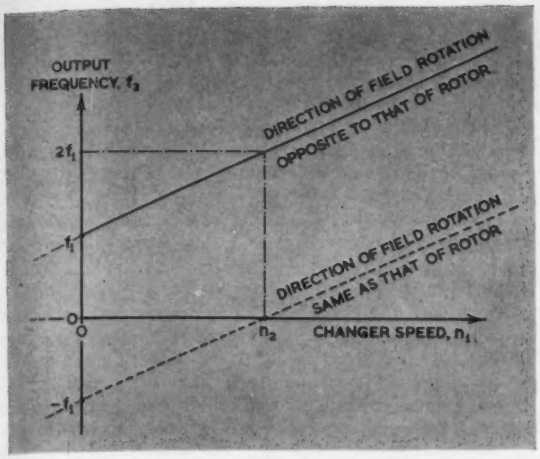


Fig. 2. Relationship between output frequency and driven speed.

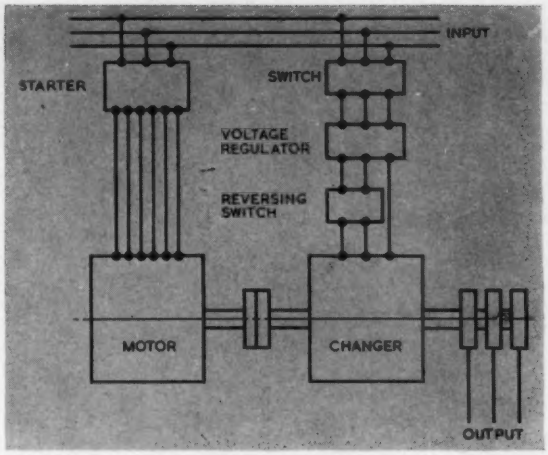


Fig. 4. Connection diagram for a frequency changer set, including voltage regulator and field reversing switch.

Thus with its rotor driven at 3,000 r.p.m. in the same direction as its field, the output would be 300 c/s. Driven in the opposite direction, the frequency would be 400 c/s. The change from 300 to 400 c/s could be effected by reversing either the drive or the changer field. In practice the latter method is always used to avoid the expenditure of energy associated with reversal of the moving parts.

Taking as another example, a changer for obtaining 25-c/s output from a 50-c/s supply, it is found that a two-pole machine can be used ($p_2 = 1$), driven at 1,500 r.p.m.

Thus $f_2 = \dfrac{1500 \times 1}{60} \pm 50 = 75$ or -25 c/s, either of which would be available from this set. (The minus sign preceding the 25 indicates that the phase sequence at this output frequency is opposite to that at 75 cycles.)

Voltage Regulation

The voltage drop when full load is applied is generally within 5 to 10 per cent, but may be greater at low power factors. No inherent voltage control is possible. Therefore, in applications requiring independent control of voltage a separate voltage regulator is provided, usually on the input side of the changer.

Fig. 4 shows the connections for a directly coupled set, using a cage motor as the drive, and including a voltage regulator. The reversing switch on the input side of the changer makes both alternative output frequencies available, and is omitted when only one frequency is required.

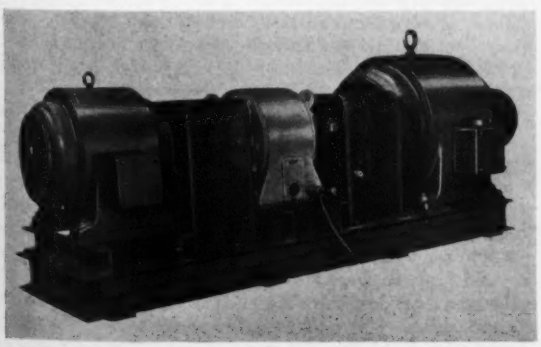


Fig. 3. Variable frequency set, incorporating a Heenan & Froude variable slip coupling. (Brook Motors Ltd.)

Power Rating

The power output from the set is provided partly by induction from the changer field, and partly by the driving motor, contributed in the following proportions (neglecting losses):

$$\frac{n_1}{n_1 \pm n_2} \times 100 \text{ per cent by the driving motor.}$$

$$\frac{\pm n_2}{n_1 \pm n_2} \times 100 \text{ per cent by the changer field.}$$

Applying these formulæ to the aforementioned fourteen-pole changer ($n_2 = 428$) driven at 3,000 r.p.m., it is seen that the 400-c/s output power is contributed in the proportions 87·5 per cent by the driving motor and 12·5 per cent by the changer. On 300-c/s operation (n_2 negative), these proportions become 116·6 per cent and $-16{\cdot}6$ per cent respectively. Thus the changer primary under the latter mode of operation would feed power back into the supply.

It is interesting to consider the power ratings of the two machines comprising the 25-c/s set, referred to previously. Since $n_1 = 1{,}500$ and $n_2 = 3{,}000$ (negative), it follows that the output power is contributed in the proportions 200 per cent by the changer and -100 per cent by the motor. Thus the changer itself needs rating at twice the output power, but half its input (neglecting losses) is returned to the supply via the motor. The motor does not in this case drive the changer, but is itself driven at slightly above its synchronous speed, and, in fact, functions as an induction generator.

In the above 25-c/s set, the combined ratings of the two machines require to be three times the rated output. Changer sets for obtaining output frequencies lower than the supply frequency tend to become disproportionately large, the more so as the frequency becomes lower. The losses are also increased.

It is to be noted that when a frequency changer is used for obtaining two or more alternative output frequencies, either by field reversal or by changing the driven speed, its rated kVA output changes in proportion to the output frequency.

Single-phase Operation

Single-phase loading is possible, the permissible rated power output from a given frame size being then reduced by nearly half.

Whether the output is single or three phase, the input to the changer must be poly-phase, as the production of a rotating field is essential to its operation. However, if a

Fig. 5. A batch of vertical 25-kVA. 60-c/s changers. (Brook Motors Ltd.)

single-phase supply only is available, this may be converted to "artificial three phase" for providing the input. A neat arrangement is the use of a Ferraris Arno pilot motor, of sufficient size to serve the dual purpose of providing both the artificial three-phase electrical input and the mechanical power for the drive.

Construction

With minor modifications, the frequency changer is constructed in a similar manner to a normal slip-ring motor. Usually the input is taken into the stator and the output from the rotor, although the opposite (or "inverted") arrangement is sometimes adopted for convenience in design.

The higher ranges of output frequencies call for the use of high-grade transformer quality core laminations, and the high speeds require thorough bracing of the rotor windings.

Cage motors are the usual choice for driving the changer. Direct coupling is preferred, although belt drives must be used when the required speed is not obtainable directly. Small sets are available with both the rotors mounted on a common shaft, as shown in Fig. 1. Another possible arrangement for saving floor space is shown in Fig. 5.

Supplying output frequencies within ± 20 per cent of the mains frequency entails the use of low driving speeds. Thus in order to ensure adequate cooling, forced ventilation may become necessary.

For variable frequencies, various drives are possible, one method being shown in Fig. 3.

Applications

The earliest and probably still the most common application is the driving of various types of woodworking machines, where motor speeds up to 24,000 r.p.m. are frequently required.

Among other applications of high-speed motors fed by frequency changers may be mentioned portable mining tools and machines for working light alloys.

The advent of nuclear energy has resulted in the development of special gas bearing compressors for circulating cooling gases through reactors. The compressors are driven by motors of up to 120 h.p. at 12,000 r.p.m.

Much American electrical equipment of all types is now being used in the U.K. and on the Continent, especially in the military field, and has created a demand for frequency changers giving 60-c/s output. Similarly, in overseas countries which are not on 50 c/s, sets with 50-c/s output for operating U.K. or continental equipment are sometimes called for.

Finally, an example of a different type of application. In the electric "stitch" welding of seamless steel tubing, an increased supply frequency is advantageous in producing more "stitches" per sec., thus permitting faster feeds and increased production. A number of changer sets with single-phase 150-c/s output in sizes up to 150 kVA. are now in operation.

ELIMINATION OF EXHAUST FUMES

THE exhaust fumes from motor vehicles, particularly from diesel engines, have often been the object of criticism. In the U.S.A. it was estimated recently that almost two-thirds of the smog in Los Angeles was due to exhaust fumes. Recent studies at the Battelle Memorial Institute, directed towards the elimination of these fumes, have resulted in the development of a silencer using a catalyst which substantially eliminates the smog-producing hydrocarbons from exhaust gas. Of greater importance is the fact that the catalyst is not de-activated or poisoned by the additives in the fuel. These additives, and the variation in the hydrocarbon content of the gas caused by acceleration and deceleration of the engine, greatly complicated the development of a suitable catalyst.

Independent lines of research are also being conducted by Battelle at Frankfurt and Geneva. At the former establishment the problem of fumes in relation to carcinogenic debilities is being studied, and new manifold and carburettor designs are being formulated to reduce the danger from these fumes. In Geneva the problem is being studied in relation to the car exhaust, and work there involves the use of cobalt as the catalyst. Trials are being carried out on vehicles and a subsequent evaluation of the data collected is expected to lead to further improvement.

In the U.K. a range of catalytic mufflers is available from Oxy-Catalyst Sales Ltd. for use on diesel engines and engines using unleaded petrol as fuel, and a number of these are now in daily use attached to engines operating in closed surroundings. These mufflers employ as the effective element the "Oxycat", which is an assembly of porcelain rods covered with a film of alumina and platinum. This gives an extremely stable and active catalytic surface which functions at temperatures at and above 230 deg. C.

Chromalloy Corporation have also announced the development of a device designed to eliminate smog-causing hydrocarbon gases from automobile engines. This unit, invented by Charles W. Morris, is designed on a mechanical principle involving a single moving part. Chromalloy estimate that the cost to the public, once the device is approved for general use by the Motor Vehicle Pollution Control Board, State of California, should be about $50. The "smog burner", as it has been called, is easily installed and is said to be effective for the whole life of the car on which it is used. It is manufactured in a specially coated heat-resistant alloy, the burning process originating with a sparking-plug which ignites the hydrocarbon gases in a cone-shaped chamber.

Universal Oxidation Processes Inc., a subsidiary of Universal Oil Products Co., are directing the manufacturing and marketing activities in connection with the Purzaust catalytic muffler, which has been developed to meet the California state requirements for effective control of automotive exhaust gases.

Stanford Research Institute, under contract to Universal, is conducting a project involving the development of tests and procedures in the field of automobile exhaust fume composition and its relation to smog formation. This is expected to have application in the studies and evaluation of the Purzaust mufflers, which are being tooled up for mass production.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture and awaiting development in the U.K.

Automatic Coil Winding Machine for Motor Armatures

THE Gagliardi universal automatic coil winding machine, which is not yet available in the U.K., represents a considerable advance in coil winding techniques. It makes the winding of wound rotors for electric motors a completely automatic operation, apart from the loading and unloading operations.

The armature is placed on a central horizontal shaft, where it is held in a pneumatically operated clamping device. Arranged radially are a number of sets of coil supports and wire stringing devices which are placed around the circumferences of two large rings. These are usually twenty-four in number. From these the copper wires pass through a group of twenty-four thread-guide plates to the armature. Both the coil supports and the wire stringing devices can be adjusted circumferentially around the two rings, which hold them in order to correspond with the thread-guide plates when more or less than twenty-four slots must be wound, or a number other than their sub-multiple. The change of finished coils is accomplished very quickly. The wire-stringing device is said to be very sensitive, and is equipped with a control regulated by a band brake placed on the shaft with the coil supports. All the pulleys are of nylon, and the thread-guide plates terminate with polished bushes to eliminate damage to the copper wire enamel. It is claimed that polyester enamels are unaffected.

An electronic programme fixing device automatically regulates the number of coils to be wound, and stops the machine when the winding has been completed. The copper wire is wound simultaneously in all the slots at an average speed of one coil per min., but this speed can be regulated. All the thread-guide plates have an automatic movement towards the shaft which allows them to place the wire at the bottom of the slots. The two winding heads are in the form of a honeycomb, thus allowing better cooling as well as more complete penetration of the insulating varnish used for impregnation.

The machine is said to be practically universal in capability, as it can wind armatures with any number of slots up to a maximum of forty-eight. Although it is claimed that numbers of slots above this figure could be wound, the demand is not great enough to require automated production. The machine can carry out the winding of armatures with inclined slots, and can also wind V-shaped coils.

With this machine it is obvious that the greater the number of slots in the armature, the greater will be the economy in time. By way of comparison with ordinary methods of production, the makers quote the following: An armature with twenty slots with forty turns per slot,

each divided into two coils of twenty turns, one with a left and one with a right inclination and with terminal leads at the beginning, the middle and the end, would be wound at the rate of 100 armatures per day. Using traditional methods, only six armatures could be wound per day.

The current consumption of the machine is approximately 200 W., and provision must be made for an air supply at approximately 40-50 p.s.i. which is consumed at the rate of about 3 litres per sec. The machine is not equipped with a compressor, but a 300 litre reservoir is provided which can contain air up to 112 p.s.i., and a filter. A transformer is provided to enable a variety of voltages to be used.

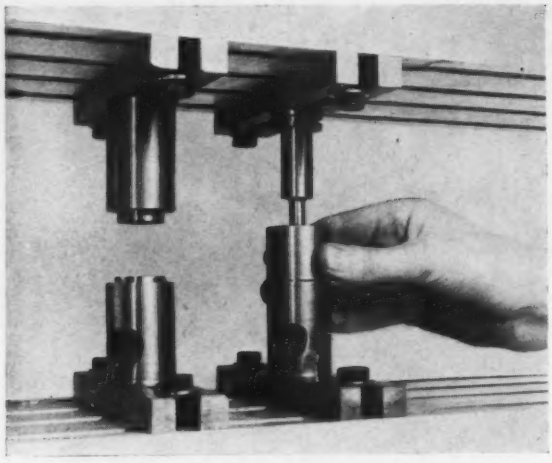
Manufacturers interested in this machine are asked to get in touch with Dixon Dupont Ltd., Cross Keys House, 56 Moorgate, London, E.C.2.

Novel Unit Tooling System for Press Brakes

ALTHOUGH the idea of producing unit tools is not new, those systems which have been produced in the past have generally been designed to enable drill jigs, press tools, etc., to be made with the minimum of drawing office time and toolroom work.

The Gold Star unit tooling system, recently introduced by P. & H. Metal Products (Kingston) Ltd., goes one step further in that it greatly extends the possible uses of the press brake, a machine generally used for bending and flanging long channels, angles and sections in sheet metal. It enables piercing and notching operations to be carried out on such components as washing machine shells, lighting fittings, trunking, cabinet and panel work without any restriction on throat depth.

The standard Gold Star equipment consists of two long, 8 in. wide slotted bolsters, provided with pillars as on a



Showing two *A* type units—the operator is using a centring bush for setting.

A 4 ft. box folder, incorporating four *A* type and one *B* type units.

conventional die set. These die sets can be fitted on most press brakes by means of a suitable clamping tenon on the top bolster and clamping brackets on the bottom bolster. The effective working length of the die set is the distance between the pillars, and may be anything from 3 to 10 ft. Normal sizes are 3, 4, 6, 8 and 10 ft. Other sizes can be produced to special order. A large variety of punching, notching, louvring and special-purpose tools may be fixed to the bolsters by means of bolts and special nuts which fit the bolster slots. Four slots are provided in each bolster, and each tool base is provided with a long slot at each side. A stagger of up to 5 in. can be obtained with the standard piercing units. Alignment of the tools by means of centring bushes is simple, and new set-ups are easily arranged, a valuable feature when the system is applied to batch production.

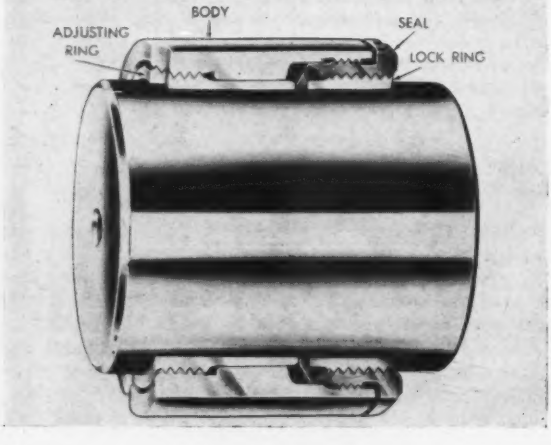
The standard piercing units supplied with the system are of the *A* and *B* types. The *A* type pierces shapes contained within $\frac{3}{4}$ in. dia., and the *B* type shapes contained within $1\frac{1}{2}$ in. dia. The *A* is machined to $1\frac{1}{4}$ in. wide and allows centres of $1\frac{1}{2}$ in. to be achieved, while the corresponding dimensions for *B* are 4 in. and 4 in. respectively. All slugs are discharged freely regardless of positioning. The punch unit casting is fitted with a withdrawable punch and a spring-loaded stripper bush in a housing. The die unit is fitted with a detachable die. It is thus possible to use the die casting, punch casting, stripper casting, stripper housing, spring, etc., again and again. Only the punch, die and stripper bush need be changed to give a different size or shape of hole.

Location of the dies when setting up is easily achieved by means of templates pierced to fit over the dies. All dies are ground to the same outside diameter, i.e. $1\frac{1}{2}$ in. for the *A* type and $2\frac{1}{2}$ in. for the *B* type.

The Gold Star system is claimed to make possible considerable production economies, particularly where a number of piercing operation must be carried out.

This system is to be shown at the Engineering, Marine, Welding and Nuclear Energy Exhibition at Olympia, *April 20 to May 4*.

Metal Hydraulic Seal for Heat and Pressure



THE BFG seal, recently developed by B. F. Goodrich Aviation Products, of Akron, Ohio, is an all-metal seal for dynamic applications, designed to handle pressure under the adverse conditions encountered in missiles and supersonic aircraft. Whereas organic seals are said to deteriorate at temperatures above 120 deg. C., the BFG seal, made of high-temperature alloy steels, is claimed to have performed satisfactorily at temperatures up to 276 deg. C., and at pressures up to 6,000 p.s.i.

The new seal does not require close tolerances, is self-compensating for reasonable misalignment and side loads, and has an extremely low break-out force. It is said to have been tested for both reciprocating and rotary motions, and is also available for static applications.

The principle involved is that of a blunt knife edge with controllable unit load that can seal pressures while holding the load on the radial edge of the seal as low as possible, thereby keeping the break-out force low.

OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Corrosion-resistant Conduit Box

Laur. Knudsen Electrical Manufacturing Co. Ltd., of Copenhagen, are marketing a universal conduit box suitable for burying under ground. Made from nylon, this junction box has twelve outlets, four in the plane of fixing, four at 45° to this and four at 90°. Each outlet accommodates either $\frac{3}{8}$ or $\frac{1}{2}$ in. conduit, and additional fittings are available to enable the box to be used as a suspended fitting.

Synthetic Mica

Although naturally occurring mica contains as many as forty elements, of these only silicon, aluminium, magnesium, oxygen and hydrogen are necessary for building up its lattice. Synthetic mica is produced by heating a charge consisting of magnesium fluoride, magnesium oxide, potassium fluoride, aluminium oxide and quartz sand to a temperature of 1,400 deg. C., at which the charge melts. The temperature is then lowered very gradually by 1-2 deg. per hr. and the melt allowed to crystallise, thus forming a product corresponding to natural mica.

According to Russian reports, a film of artificial mica can withstand an electrical potential of 7,000 V., in contrast to 4,500 V. for natural mica having the same thickness. The dielectric properties of artificial mica are preserved up to a temperature of 600 deg. C., while natural mica loses its dielectric properties at 300 deg. C.

The availability of synthetic mica has made it possible to develop entirely new insulation materials. One of them is Novomikaleks, a mixture of moulded glass and mica which does not lose its dielectric properties even at 900 deg. C. Another new material is mica ceramic, which is not affected by sharp fluctuations of temperature (it can be heated until it glows and then submerged in water, without damage). Foam mica is another new material having stability at high temperatures, a low specific weight, and a capacity to transmit radio waves.

The Bureau of Mines, at Norris, Tennessee, under an accelerated research programme sponsored by the General Services Administration, have developed a method of forming tiny flakes of synthetic mica into paper-thin sheets that may prove superior to natural mica for certain uses in electronics. This material is obtained by crystallising a melted mixture of feldspar, sand, magnesia, lithium fluoride and other minerals, and although it has a tendency to absorb water, it has strength and flexibility, high dielectric strength, and better retention of properties than natural mica.

Pilot production of synthetic mica paper (Synthamica 202) has also been announced by the Synthetic Mica Co., a division of the Mycalex Corp., of the U.S.A. This mica paper, which ranges in thickness from 0·002-0·007 in., with a melting temperature of 1,365 deg. C. and an operating temperature up to 1,000 deg. C., is suitable for use in high-temperature transformers, motors and capacitors. Its excellent electrical properties include a dielectric constant of 3-4, with a dissipation factor of 0·0005-0·0020, a dielectric strength of 600-1,000 V./mil., and volume resistivity 5×10^{15} ohm-cm. at room temperature. This paper also has a tensile strength of 5,000-10,000 p.s.i., making it an excellent material for components of electronic devices such as computers, and radar and missile-guidance systems.

Friction Welding

Friction welding is a process where mating surfaces reach actual welding temperature from the heat of friction. This heat is developed by rotating or sliding upon one another the abutting ends of two plastics, ceramic or metal cylinders. When sufficient heat has developed, and certain other conditions are reached, the motion between the two rubbing surfaces is rapidly stopped. The objects are then fused together. With proper control, the welds are as refined as those produced by electron beam welding. Good friction welding depends on the proper selection of several parameters, including speed, pressure and time.

The American Machine & Foundry Co. have developed a friction welder for metals which melts the interface surfaces. Fluidity during the welding cycle prevents the formation of harmful oxides and inclusions in the weld.

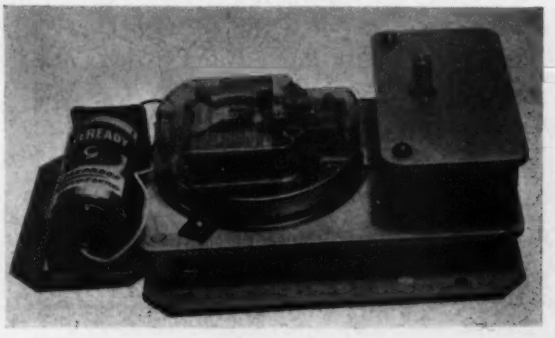
Many dissimilar materials can be joined together by friction welding, e.g. brass to copper, aluminium, low-carbon steel and stainless steel. Studies are being carried out for welding Monel to aluminium and stainless steel, and zirconium to low-carbon steel. In plastics, friction welding will join together nylon, acetal and acrylic resins.

Chronometrically Governed d.c. Motors

A new range of chronometrically governed d.c. motors, of which the exceptionally high accuracy and long life at constant speed are independent of load, line and temperature variations, has just been announced in the U.S.A. by A. W. Haydon Co. The 1·5 V. motor operates for more than two years on a standard flashlight battery, and when used as a clock drive, a constant speed of 150 r.p.m. is maintained by the governor's patented balance wheel/hairspring mechanism, with an accuracy of ±10 sec. in 24 hr., even with an input voltage range of from 0·9 to 1·8 V.

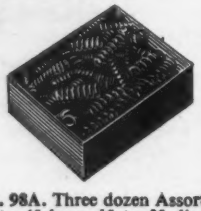
The unusual design of the governor causes the motor circuit to be constantly pulsed at intervals controlled by a jewelled escapement, so that when the battery voltage is high the motor rotor attempts to turn rapidly, but shuts off its own current at frequent intervals to automatically compensate for the high voltage. When the voltage is low, current flows to the rotor for longer periods, maintaining the average speed. In this way, rated speed is maintained with the accuracy specified, despite wide line voltage variations.

The A. W. Haydon Co. cordless motor, with battery and gear train for chart drive.



EXPERIMENTAL SPRINGS?

No. 1200. Three dozen Assorted Light Expansion Springs, suitable for carburettor control, etc. **15/-.**

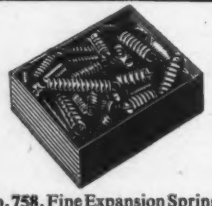


No. 98A. Three dozen Assorted 1″ to 4″ long, $\frac{1}{4}$″ to $\frac{3}{4}$″ diam., 19G to 15G. **6/6.**

No. 753. Three dozen Assorted Light Expansion $\frac{1}{4}$″ to $\frac{1}{2}$″ diam., 2″ to 6″ long, 22 to 18 S.W.G. **12/-.**

No. 760. Three dozen Assorted Light Compression Springs. 1″ to 4″ long, 22 to 18 S.W.G., $\frac{1}{4}$″ to $\frac{1}{2}$″ diam. **7/6.**

No. 757. Extra Light Compression, 1 gross Assorted, $\frac{1}{4}$″ to $\frac{7}{16}$″ diam., $\frac{1}{2}$″ to 2$\frac{1}{2}$″ long, 27 to 19 S.W.G. **18/-.**



No. 758. Fine Expansion Springs. 1 gross Assorted $\frac{1}{4}$″ to $\frac{1}{2}$″ diam., $\frac{1}{2}$″ to 2″ long, 27 to 20 S.W.G. **18/-.**

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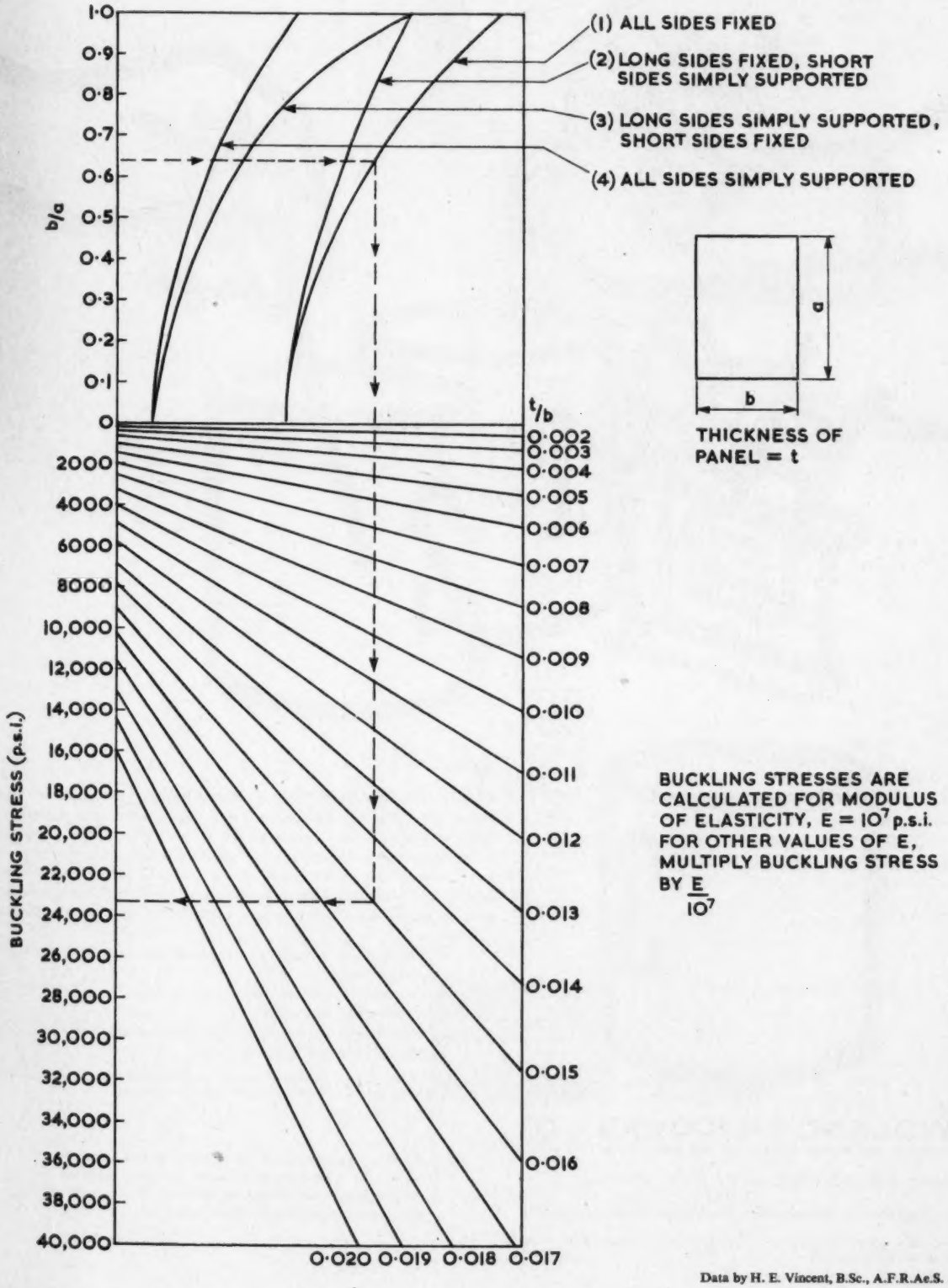
MT31

BUCKLING STRESSES OF FLAT PLATES IN SHEAR

Engineering Materials and Design
DATA SHEET No. 60



BUCKLING STRESSES ARE CALCULATED FOR MODULUS OF ELASTICITY, $E = 10^7$ p.s.i. FOR OTHER VALUES OF E, MULTIPLY BUCKLING STRESS BY $\frac{E}{10^7}$

Data by H. E. Vincent, B.Sc., A.F.R.Ae.S.

EMD 6397 for further information

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(MS)

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MATERIAL	PROCESS															
	Brazing	Gas Welding (Oxyacetylene)	Metal Arc (Coated Electrode)	Inert Gas Shielded Tungsten Arc	Inert Gas Shielded Metal Arc	Resistance—Spot	Resistance—Seam	Resistance—Projection	Resistance—Butt and Flash Butt	Cold Pressure	Pressure with Some Heat (Solid Phase)	Thermit	Ultrasonic	Electron Beam	Bronze Welding (Arc)	Bronze Welding (Gas)
Ferrous Metals																
Cast iron	B	Ap	Ap	X	X	X	X	X	X	X	X	B	X	X	B	B
Steel, mild (low carbon)	A	A	A	A	A	A	A	A	A	X	A	A	—	X	A	A
Steel, medium and high carbon	B	Ap	Ap	A	A	Bh	—	Bh	B	X	A	A	—	X	B	B
Steels, low alloy:																
High tensile structural (e.g. BS 968)	—	Ap	Ap	A	B	Bh	—	Bh	—	X	—	A	—	X	—	A
1% Cr, 0·5% Mo	B	A	Ap	A	B	—	—	—	—	X	As	—	—	X	B	B
2·25% Cr, 1% Mo	B	Aph	Ap	A	B	—	—	—	—	X	Ahs	—	—	X	B	B
5% Cr, 0·5% Mo	B	Aph	Ap	A	B	—	—	—	—	X	Ahs	—	—	X	B	B
3½% Ni	B	As	As	A	B	—	—	—	—	X	—	—	—	X	B	B
Steels, higher alloy:																
13% Mn	—	X	Bs	—	—	—	—	—	—	X	X	—	—	X	—	—
stainless steels, ferritic	B	C	B	A	A	A	A	A	—	X	—	—	—	B	B	B
stainless steels, martensitic	B	C	Bs	A	A	—	—	—	—	X	—	—	—	B	—	—
stainless steels, austenitic	B	B	A	A	A	A	A	A	—	X	—	—	—	A	B	B
Non-ferrous Metals																
Aluminium 1, 1A, 1B, 1C	B	A	B	A	A	B	B	X	A	A	—	X	A	B	X	X
Aluminium alloys:																
Al-Mg N4	C	B	C	B	B	B	B	X	A	C	—	X	B	—	X	X
Al-Mg N5, N6	X	C	D	A	A	B	B	X	A	X	—	X	B	—	X	X
Al-Mg-Si H9, 10, 20, 30	B	B	C	B	B	B	B	X	B	X	—	X	B	—	X	X
Al-Mn N3	B	A	B	A	A	B	B	X	A	B	—	X	B	B	X	X
Al-Cu-Mg-Si HI5	X	X	X	C	C	A	A	X	B	X	—	X	B	—	X	X
Al-Zn-Mg-Cu	X	X	X	D	D	A	A	X	—	X	—	X	B	—	X	X
Copper tough pitch	B	X	X	C	B	Cs	Cs	X	B	A	B	X	B	B	B	B
Copper phos. deoxidised	A	B	C	B	B	Cs	Cs	X	B	A	B	X	B	B	B	B
Copper O.F.H.C.	A	B	C	B	X	Cs	Cs	X	A	A	B	X	B	A	B	B
Copper alloys:																
manganese bronzes	A	B	Cs	C	B	—	—	—	—	—	—	—	—	—	—	—
brass	A	C	C	B	C	C	—	—	—	X	—	X	—	X	B	X
tin bronzes	B	C	C	C	B	—	—	—	—	X	—	X	—	—	C	C
silicon bronzes	B	B	B	B	B	—	—	—	—	X	—	X	—	—	B	B
aluminium bronzes	C	D	C	B	B	—	—	—	—	X	—	X	—	—	X	X
cupro-nickel	B	Bs	Cs	B	B	—	—	—	—	X	—	X	—	—	X	X
Gold	A	B	X	B	X	—	—	—	—	B	A	X	—	A	—	—
Lead	X	As	X	X	X	X	X	X	X	B	B	X	X	X	—	—
Magnesium	C	C	X	B	C	C	C	X	C	X	C	X	—	C	—	—
Magnesium alloys:																
Mg-Mn	D	C	X	B	C	C	C	X	—	X	—	X	—	D	—	—
Mg-Al-Zn	D	C	X	B	C	C	C	X	—	X	—	X	—	D	—	—
Mg-Zn-Zr	D	X	X	B	C	C	C	X	—	X	—	X	—	D	—	—
Mg-Al	D	C	X	B	C	C	C	X	—	X	—	X	—	D	—	—
Nickel	B	B	B	A	A	B	B	B	B	—	—	X	—	B	—	—
Nickel alloys: Monel	B	B	B	A	A	B	B	B	B	X	X	X	—	B	—	—
Inconel	B	B	B	A	A	B	B	B	B	X	X	X	—	B	—	—
Hastelloy A	—	C	—	B	—	B	B	B	B	X	X	X	—	B	—	—
Hastelloy B	—	C	B	B	—	B	B	B	B	X	X	X	—	B	—	—
Hastelloy C	—	C	B	B	—	B	B	B	B	X	X	X	—	B	—	—
Hastelloy D	—	C	—	B	—	B	B	B	B	X	X	X	—	B	—	—
Nichrome	B	B	X	A	X	B	B	B	B	X	X	X	—	B	—	—
Nimonic 75	B	B	C	A	A	B	B	B	B	X	X	X	—	B	—	—
Nimonic 80, 90	B	X	D	B	B	B	B	B	B	X	X	X	—	B	—	—
Platinum	B	B	X	A	X	B	—	B	—	X	B	X	—	B	—	—
Silver	B	B	X	B	X	X	X	X	—	X	B	X	—	B	—	—
Titanium CP	Bs	X	X	Bi	Bi	A	A	B	A	—	—	X	—	A	—	—
Zinc	X	Cs	X	X	X	—	—	X	X	X	X	X	—	X	—	—
Zirconium Zircalloy 2	Bs	X	X	Bi	Bi	B	B	B	B	—	B	X	—	A	—	—

Engineering Materials and Design

DATA SHEET No. 61

WELDING GUIDE

WELDING GUIDE

This chart has been prepared by courtesy of the British Welding Research Association, and is intended as a guide in selecting a suitable welding process for the materials mentioned. Many factors, for example section thickness, enter into this choice, and not infrequently a technique is used which is far from the optimum as regards performance, but which has some feature making it particularly suitable for a specific component. Much of the work of the B.W.R.A. is devoted to assisting its members in such choices.

WELDING SYMBOLS

A	Very good
B	Good
C	Fair
D	Poor
X	Impractical

OTHER SYMBOLS

i	Must be welded in an inert gas filled chamber or with special inert gas shielding.
v	Must be welded in a vacuum chamber.
p	Preheat usually required.
h	Post-weld heat-treatment necessary.
s	Other special precautions.

EMD 6398 for further information

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EMD 24

New Books

Progress in Semiconductors, Vol. 5. *General editor Alan F. Gibson. (Heywood & Co. Ltd.—63s.)*

To set out to produce annually a comprehensive and authoritative survey of recent developments in the semiconductor field is a venture calculated to discourage the most intrepid scientific compiler, but in this, the fifth volume of his series, Dr. Gibson has again demonstrated his ability to produce a smooth and cogent appraisal of the past year's significant semiconductor developments.

With a subject so vast, and with an ever-increasing number of research teams the world over making use of a constantly growing range of equipment, the selection of half a dozen or so subjects to represent a year's universal effort is itself a task calling for the utmost discretion and restraint. Add to this the real need for the brand of editing which ensures a high standard of uniformity in the method of presentation of this varied material, and some idea of the magnitude of this annual operation can be obtained.

Following the now-familiar pattern, this volume presents information in the form of papers submitted by recognised authorities on the subjects covered. The optical properties of semiconductors receive more than their usual attention, it being realised that the high resolution spectroscopes developed during the past few years can supply an enormous amount of quantitative information about these substances. Two of the papers are devoted to this aspect of semiconductor theory, and constitute in effect a neat summary of a subject which has until now been scattered through the learned journals.

As might be expected, a regular feature of these volumes is a discussion or appreciation of substances which have arrived comparatively recently in the semiconductor family circle, and this time it is graphite and indium antimonide which receive due recognition. Other subjects dealt with are the thermal conductivity of semiconductors, the electrical properties of semiconductor surfaces, and the classification of semiconductors in terms of the chemical bond picture.

M. Eades

Materials in Nuclear Applications. *(A.S.T.M. special technical publication No. 276—$8.52; $6.60 to members.)*

This book contains selected papers from four symposia. Three of these symposia were presented at the Third Pacific Area National Meeting of the American Society for Testing Materials, and consisted of "Radiation Effects and Dosimetry", "Post-radiation Effects in Polymers" and "Ceramics in Nuclear Energy". The fourth symposium, on "Technical Development in the Handling and Utilisation of Water and Industrial Waste Water", yielded two papers, viz. "Disposal of Industrial Radioactive Waste Waters at Hanford" and "Determination of Radioactive Materials in Water". A further paper on "Radiation Effects in Steel" has been included in the section of the book devoted to the symposium on "Radiation Effects and Dosimetry", since it is in effect a comprehensive review of the literature on the subject. Of particular interest to the designer are the post-radiation dielectric properties of silicones and the effect of gamma radiation on some electrical properties of polytetrafluoroethylene resins (p.t.f.e.).

Hyperstatic Structures, Vol. 2. *By J. A. L. Matheson and A. J. Francis. (Butterworths—60s.)*

Practical structural configurations are rarely made statically determinate, and the structural engineer's problems are primarily the analysis of structures with several degrees of redundancies. It is therefore significant that a collective treatment of statically indeterminate structures has been made in this book.

Advanced students of the theory of structures, or those following up this subject in industry, will find the relations and applications of contemporary methods clearly demonstrated by worked examples. Although the examples and problems set for solution constitute the major part of this volume, it is effectively a self-contained study. This is achieved by a separate chapter relating the energy theorems, and by introducing each section with a brief résumé of the theorems fully expounded in the first volume. The versatility of the energy methods is used to full advantage, presenting refined solutions which ease the lengthy computations associated with these problems.

Predominantly, the examples feature framed structures and arches, and give a very comprehensive treatment of the various types. Deflection and stability aspects are also related to these structures. Matrix methods included form an ideal introduction to the arrangement of these problems for solution by digital computers.

The ultimate value of this approach to study by presenting worked examples is controversial. However, in the book the choice and scope of examples does much towards simulating industrial experience for the progressive structural engineer.

G. Hills

A Textbook on Light. *By L. Mackinnon. (Longmans Green—17s. 6d.)*

This book presents an admirable introduction to geometrical and physical optics for a student proceeding to the advanced or scholarship level of the G.C.E. or the University Entrance Scholarship Examination. The approach is from experimental science, and many practical illustrations are given. The student is strongly encouraged to make his own contribution in thinking out the implications of the matter presented, and is given excellent guidance and encouragement. There are ample examples for calculation drawn from scholarship papers, and some invaluable remarks on the technique for tackling examination questions that will not come amiss to many looking in this book for guidance in the solution of some incidental optical problem in their work.

The book is well laid out, with few typographical errors, and the diagrams are very clear, although in a few cases a diagram seems to have been inserted a page late. The matter includes an excellent introduction to the nature of light, reflection and refraction, and an account of the history of the measurement of the velocity of light. Photometry is dealt with, and there are well-arranged sections on diffraction and interference, and the elements of polarisation phenomena; also a brief account of optical spectra. The chapters on geometrical optics cover the basic theory of lenses and mirrors from a study of wavefronts, and lead to an introduction to the simpler optical instruments. The sign convention used is described in an appendix, but is unfortunately not that which is generally used in more advanced studies.

The concluding chapter stimulates interest by outlining some more advanced optical topics, including the photoelectric effect, stellar interferometry, the determination of the metre in terms of light wavelengths (the 1960 redefinition is not mentioned) and the Michelson-Morley experiment.

Altogether, a pleasing book, easy to read, which attains its object of providing a bridge between the spoon-fed optics of the classroom and the lectures of the university.

J. W. Gates

Advances in Cryogenic Engineering, Vol. 5. *Edited by K. D. Timmerhaus. (Plenum Press—$15.)*

Each year a conference is held in the U.S.A. which is fast becoming one of the most important forums for the exchange of technical information in all branches of cryogenic engineering. Under the spur of space flight, an intensive effort is being made throughout the world in the study of the low-temperature regions of liquid oxygen, liquid hydrogen and liquid helium. As the development programmes proceed, new problems assert themselves and fresh objectives have to be reached. The papers and discussions at the conference are reported fully in this publication.

The high standard maintained by the conference selection committee has attracted contributions from recognised authorities and research workers from universities, industry and government establishments in the U.S.A. and Europe. Each volume deals with one complete annual conference, and contains a wealth of detailed information which could only otherwise be compiled by an extensive search of published literature. These volumes together make up an encyclopædia of up-to-date information vital to scientists and engineers interested in cryogenic engineering.

D. H. Tantam

New Features at
THE ENGINEERING, MARINE, WELDING & NUCLEAR ENERGY EXHIBITION

OLYMPIA · LONDON · APRIL 20 to MAY 4 · 1961

Powder Weld Torch

With the addition of a simple adaptor to the proven Schori 50 spraying pistol, a torch is obtained for hardfacing a wide variety of work. It uses standard Deloro Stellite powders and does not operate on the injection principle (argon is the con-

veying gas, so that compressed air is unnecessary). It is readily adaptable to automatic hardfacing. Demonstrations of sprayfusing (shown in the illustration being applied to a Scimitar aircraft arrester hook), powder welding, fusing by induction heating and gas deposition of the Stellite alloys will be carried out regularly, and samples for examination will be available.

Also on show will be a range of cutting alloys in solid or tipped form for all purposes, including tooling for automatics, capstans, centre-lathes and milling machines. *Deloro Stellite Ltd.*, Highlands Road, Shirley, Solihull, Warwickshire.

EMD 6477 for further information

New Torquemeter

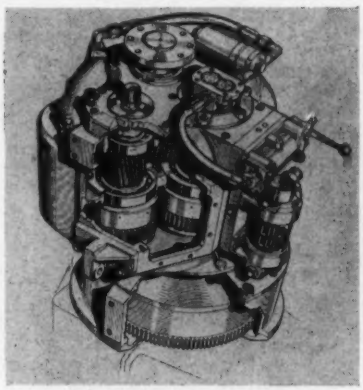
A mechanical torquemeter known as the TMR-3, which gives continuous readings from zero to 850 lb. ft. at speeds from 0-25,000 r.p.m. with negligible power consumption, has been developed by this company. The instrument can be fitted as a permanent attachment between the output shaft of a prime mover and the input shaft of a driven machine, using either a base mounting or side mounting flanges co-axial with two coupling shafts. The twist exerted on a torsion bar is magnified by a train of epicyclic gears and transmitted to an indicator, the dial of which is graduated in lb. ft. Since the only function of the gears is to measure the twist of the torsion bar, they are made conveniently small and enclosed in a compact casing.

The torsion bar, through which all power is transmitted, has serrations at each end to engage with the two coupling shafts. The inner ends of these two shafts are provided with dogs or spurs which are permanently intermeshed with suitable clearances, so that no weight is taken upon them unless the torsion bar fails or the torquemeter is overloaded. Should this occur the whole load is immediately taken on the dogs instead of on the gearing. A 230 V. a.c. synchro-torque transmitter is coupled to the indicator for use with a synchro-torque receiver and indicator when instrumentation is required remote from the torquemeter. For more accurate measurement of lower torques, torsion bars of greater flexibility with the appropriate dials can be provided. *Sir George Godfrey & Partners (Industrial) Ltd.*, Hampton Road West, Hanworth, Middlesex.

EMD 6478 for further information

New Gearboxes

The range of hydraulic reverse/reduction gears built by Masson, of France, is to be introduced for the first time by the U.K. concessionaires. The gearboxes that



form the Masson range are designed to cover engines ranging from 25 to 1,500 h.p. Reduction gears with ratios up to 5:1 are available for all models. Provision has also been made for a power take-off to be fitted which is capable of transmitting 10 per cent of the effective gearbox power. Additional features of the gearboxes include an externally fitted oil pump and filter, and an oil cooler to ensure operation at the most efficient temperature. *Marine Power (Poole) Ltd.*, 118 Market Street, Poole, Dorset.

EMD 6479 for further information

Return Bends

New developments are short radius return bends for arduous conditions, as encountered in oil heaters for the petroleum industry. Experience has shown that forged steel return bends, which are free from blow holes and other weaknesses, give long and trouble-free service. The bends are made in mild steel and chromium molybdenum alloys.

Tangent return bends, i.e., bends with straight legs, have been specially developed for the speedy construction by flash butt welding of heating coils for heat exchangers. Branch bends and a full range of welding fittings in carbon alloy and stainless steels will also be featured. *B.K.L. Alloys Ltd.*, Birmingham Factory Centre, Kings Norton, Birmingham, 30.

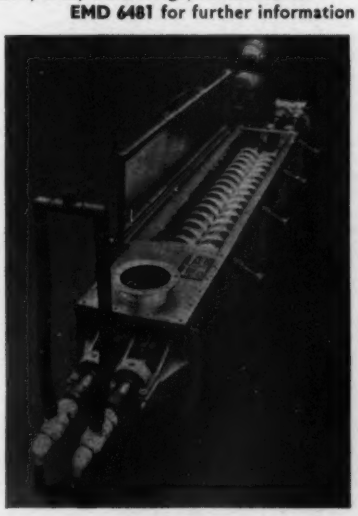
EMD 6480 for further information

Continuous Heat Exchanger

The Holo-Flite processor is a continuous indirect heat exchanger that combines maximum heat transfer area with minimum space requirements. Being designed as a screw conveyor with helical hollow flights through which the heat transfer agent is circulated, it conveys the material to be heated, cooled or dried at a uniform predetermined rate. The rotating screws are mounted in a trough, and the assembly of screws, trough, bearings and drive gear is the basic unit.

The heat transfer agent is completely isolated from the material being processed, and heat is transferred to or from the heat transfer agent by contact with the hollow flights. The unique and patented feature of intermeshed rotating screws causes the particles of material within the mass to be subjected to continuous movement by the flights, and in constantly changing position they make frequent and repeated contact with the heat transfer surfaces. The slow conveying, interfolding and dispersing action of the intermeshed screws is so gentle that there is no dusting, and a minimum, if any, abrasion of solid particles. *Holdan Engineers (London) Ltd.*, Turnbridge, Huddersfield.

EMD 6481 for further information



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New Features at THE ENGINEERING, MARINE, WELDING & NUCLEAR ENERGY EXHIBITION · 1961

Rubber Gearwheels

Engineering components in Prescollan will be a feature of this company's exhibits. Prescollan has exceptional resistance to tearing, abrasion and impact, and the harder grades, due to a high modulus, combine the advantages of rubber and

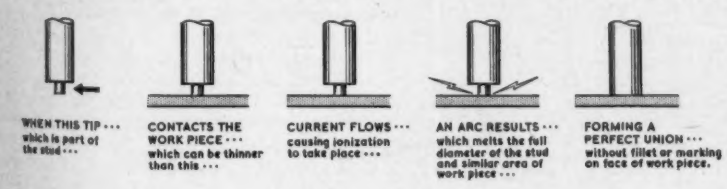
plastics. Prescollan components include silent gearwheels, conveyor pads, gaiters, diaphragms, rollers and hammer heads. *John Bull Rubber Co. Ltd.* (Mechanical Products Division), Leicester.

EMD 6482 for further information

"Stored Energy" Stud Welding

An interesting exhibit will be the "stored energy" stud welding process now being distributed in this country under licence from the American originators. Welding is produced by initiating a low-voltage high-amperage discharge. When the patented tip of the stud contacts the base material, capacitative energy of 300,000 A. per sq. in. at 80 or 90 V. fuses the tip at its point of contact on the plate without dispersing the molten metal beyond the edges of the stud. Distortion is avoided because the arc, and therefore the heat generated, are confined to the tip of the stud, thereby making it possible to use this method of welding on material as thin as 0·02 in. It may also be used effectively for welds on the reverse sides of plated, painted, enamelled and ceramic or plastics-coated surfaces without any risk of damage to the coatings. Threaded and unthreaded welding studs of steel, copper, brass and aluminium are supplied in standard sizes. Also on show will be new developments in ultrasonic cleaning techniques and machining. *Kerry's (Ultrasonics) Ltd.*, Warton Road, Stratford, London, E.13.

EMD 6483 for further information


WHEN THIS TIP ··· which is part of the stud ···
CONTACTS THE WORK PIECE ··· which can be thinner than this ···
CURRENT FLOWS ··· causing ionization to take place ···
AN ARC RESULTS ··· which melts the full diameter of the stud and similar area of work piece ···
FORMING A PERFECT UNION ··· without fillet or marking on face of work piece.

Fuel Oil Additive

Additives are used to improve the storage qualities and pumpability of furnace fuel oils, to obtain improved combustion, to decrease deposits in boilers, and to minimise the corrosive contents of flue and funnel gases. Duramis has the property of diffusing rapidly throughout a tank of fuel to give a uniform concentration, and it enables all types of oil fuel to be delivered to the burners in the optimum condition. In addition to reducing sludge and soot deposits and reducing corrosion effects, Duramis decreases the surface tension of the fuel oil, giving smaller droplet size, and thus enabling more complete combustion to take place. *Duramis Fuels Ltd.*, Porchester, Nr. Fareham, Hants.

EMD 6484 for further information

Heat Insulation

A new type of calcium silicate insulation, known as Paratemp, has been specially developed for the chemical, petroleum and similar industries. Paratemp has a uniformly low thermal conductivity between 93·3 and 760 deg. C., a compressive strength at 5 per cent deformation of 70 p.s.i., a modulus of rupture of 60 p.s.i., and a density of about 12 lb./cu. ft. The material is chemically inert, and retains most of its strength even after long exposure to its limiting temperature; it is undamaged by wetting and dries without deformation or loss of thermal efficiency. Linear shrinkage after heating for 24 hr. at 650 deg. C is 1-2 per cent with a 12 per cent loss of weight.

Darlington 85-per-cent super magnesia, made by the same company contains 85 per cent magnesium carbonate reinforced with asbestos fibres, and is made by a process which causes a chemical bond between the two. This produces a very high resistance to moisture with high compressive and mechanical strength, so that it can safely be used as a catwalk or ladder support, etc. The material is rot-proof, odourless, fireproof, inert and can be precision moulded in any shape or size. It provides good insulation at temperatures up to 343 deg. C. *The Chemical & Insulating Co. Ltd.*, Darlington, Co. Durham.

EMD 6485 for further information

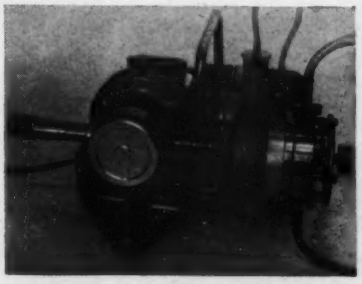
Extruded Steel Sections

A comprehensive range of steel extrusions will be shown by this company, together with some of the more recent interesting and difficult extrusions that have been carried out. The number of applications is very large, and the range of industries which at present use steel extrusions is very extensive, varying from heavy engineering, ship-building, etc., down to light and precision engineering. *Alexander Marcar & Co. Ltd.*, 4 St. James's Street, London, S.W.1.

EMD 6486 for further information

New Pumps

The Engineering Division will be showing the latest addition to the Micro pump series, a model specially developed for use in hospitals, where small quantities of liquid must be accurately metered for intravenous injections, tube feeding, etc. They will also be exhibiting a duplex version of the D.C.L. M type metering pump (in which two pump mechanisms are driven from one motor), and an improved liquid carbon dioxide pump.



The Chemical Division will show its new 50 lb. syphon cylinder, designed to supply practically moisture-free carbon dioxide to welding sets in the shrouded arc process. The cylinder valve is fitted with a dip tube passing down inside the cylinder, so that only liquid is withdrawn when the valve is opened. The liquid then passes through a vaporising heater, which may be incorporated in the welding set. This ensures that the composition of the gas delivered to the weld site is substantially uniform, while its moisture content is never more than 0·015 per cent and usually much less. *The Distillers Co. Ltd.*, 21 St James's Square, London, S.W.1.

EMD 6487 for further information

EMD 6402 for further information

MS FLUID FACTS

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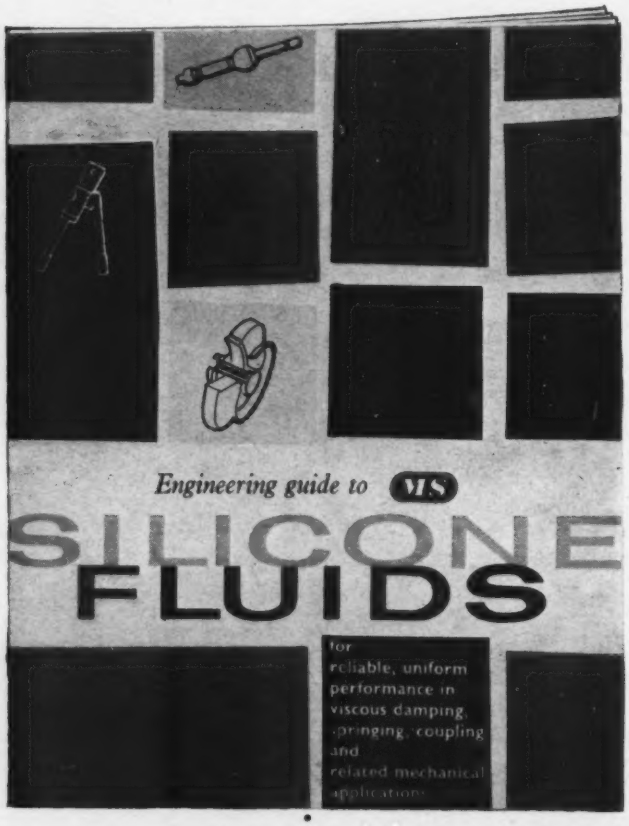

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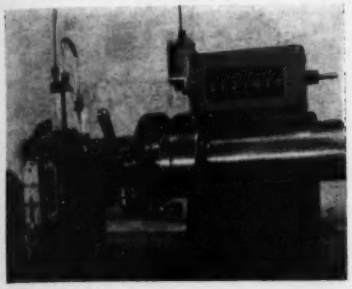
MSF8

New Features at THE ENGINEERING, MARINE, WELDING & NUCLEAR ENERGY EXHIBITION · 1961

Hydraulic Revolution Counter

The Manzel hydraulic pump and actuator assembly is designed to operate a revolution counter. An advantage over the electrical method is that there are no maintenance problems. The assembly comprises a pump unit housed in a steel container, and as fitted to the Doxford engine it is operated by the normal type



of lubricator driving lever working on an eccentric fixed to the camshaft which drives the cylinder lubricators. Every rotation of the eccentric gives an impulse of oil which is pumped through a small-bore copper pipe to the counter actuator mounted on the revolution counter at the engine control station. This impulse of oil ejects a plunger which trips the counter mechanism, and by a spring return, the plunger is withdrawn, automatically returning the working impulse of oil to the pump unit, ready for the next power stroke. During the power stroke more oil is pumped than is actually required to effect this movement. This surplus offers a safety working margin which is diverted back to the reservoir via a relief valve set at the predetermined working pressure. This overspill can be clearly seen, for it passes to the reservoir via a transparent sight feed dome. *British Manzel Oil Pump Co. Ltd.*, Durranhill Road, Carlisle.

EMD 6488 for further information

Non-destructive Testing of Steel Bearings

The main exhibit on this stand will be the new Mark I Bondmeter, designed for the non-destructive testing of adhesion in steel-backed bearings with white metal linings up to 0·1 in. thick. Electronic probes are passed over the surface of the bearings. The result, displayed by an optical galvanometer, is compared with that from an appropriate reference standard, and serves to show whether satisfactory bonding has occurred between the bearing shell and the lining. The instrument is calibrated for use with the Hoyt Number 11 group of anti-friction metals, and since the test is non-destructive it can be applied 100 per cent to production. A further possible use for the instrument is in carrying out routine inspections to discover whether the bond between the white metal and the steel of a bearing has weakened due to operating conditions, such as may occur through electrochemical attack. Also on show will be electrically heated melting pots and ovens, solders, tinning compounds, anti-friction metals, non-ferrous products and a display of precision-finished plain bearings and bushings in a variety of metals. *The Hoyt Metal Co. of Great Britain Ltd.*, Deodar Road, Putney, London, S.W.15.

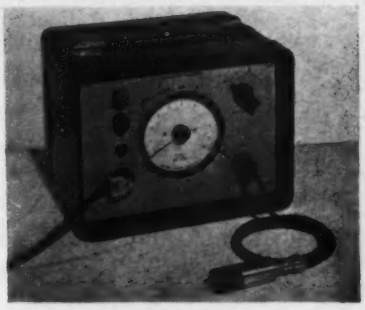
EMD 6489 for further information

Testing Machine

The Avery universal testing machine is fitted with a new design of self-contained servo-operated autographic recorder which has a rate of response of less than 2 sec. full scale, and which records load and extensions in both directions. Being servo operated, it can be located away from the machine and does not influence the accuracy of the machine or extensometer. Provision is made for one ordinate to plot time against extension or load if required.

The features of the latest visual hardness testing machine are high magnification of ×350, optical projection of image on to screen, improved shutter-type reading device operated by digital micrometer to facilitate rapid reading of size of impression, rapid production rate and reduction of operator fatigue. *W. & T. Avery Ltd.*, Birmingham.

EMD 6490 for further information



Transistor Tachometers

Among the many exhibits on this stand will be portable transistorised tachometers working from a photo-probe or magnetic pick-up. Both will operate from either a mains or an external 12 V. battery supply, the rotation speeds in three ranges being clearly indicated on a 6¼ in. circular scale. The accuracy is essentially that of the meter, which is 1 per cent of full-scale deflection. The errors introduced by the circuit are negligible when the supply voltage is at its normal value, and do not exceed an additional 1 per cent for supply changes of ±10 per cent. *Southern Instruments Ltd.*, Frimley Road, Camberley, Surrey.

EMD 6491 for further information

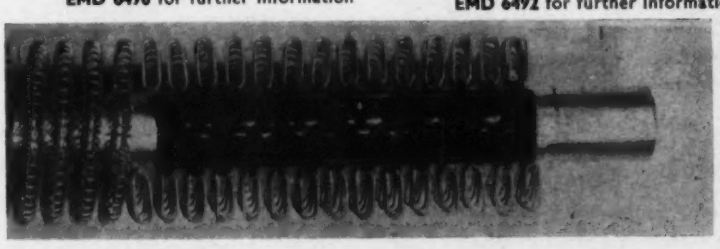
Heat Exchanger

The new "Clayton-Still" heat exchanger has an extended surface consisting of a continuous wire wound into elongated loops which are firmly bonded to the basic tube in a helical formation. As the rate of heat transfer to or from a small-diameter wire is extremely high, the resultant large dissipating surface, aided by air turbulence induced by the formation of the wire, gives a very high coefficient of heat transfer.

Wound tubes, with basic tube diameters of ½ to 3 in. and overwire diameters of ¼ to 4½ in. can be supplied in up to 25 ft. lengths, and may be made from copper, copper alloys, brass, mild steel and stainless steel.

Two special types of tube have been evolved for the cooling of oils and other hydrocarbon liquids. In both cases the inner surface (as well as the outer, if required) is extended: in one case by the insertion of three small-diameter tubes (usually only used when the liquid contains large flakes of suspended matter), in the other by the bonding-in of a spiral looped wire formation. This latter is now available without a centre rod, so that it can be used in applications where the rate of heat exchange and the fluid pressure drop are critical. *Clayton Dewandre Co. Ltd.*, Titanic Works, Lincoln.

EMD 6492 for further information



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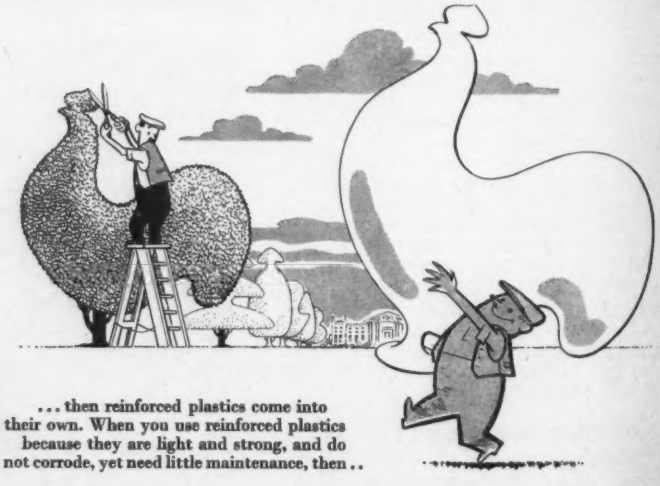

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EMD 6404 for further information

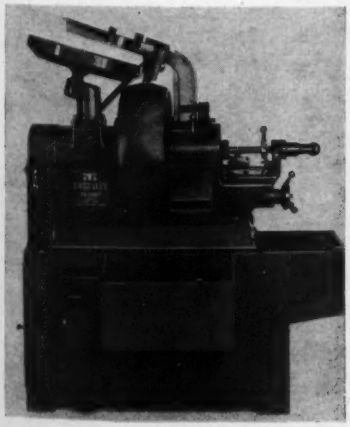
New Features at THE ENGINEERING, MARINE, WELDING & NUCLEAR ENERGY EXHIBITION · 1961

New Lathe, and Screw Thread Machine

The Crossley-Beer double-ended taper turning lathe will be shown for the first time, the object of this machine being to produce identical tapers in the bore of a valve body and on the valve plug of taper valve cocks—with consequent precision fit as machined. The unit may also be used for producing other types of mating conical component. By arranging the spindles in a central headstock, the identical taper is set on both sides of the machine, and no special adjusting is required, resulting in short preparation times. Big reduction or complete elimination of hand lapping is obtained, the precision fit of the mating parts being as machined.

Also being shown for the first time is the Crossley-Trurnit precision screw thread hammering machines, which represents a technological advance in the production of wood screws by a cold forming process with no cutting of threads. Slowly rotating, the screw blank is hammered at a rate of up to 6,000 blows per min. by rotating dies operating radially inwards and encircled by a hollow cam wheel. Because the screw blank elongates in the process of being hammered into a finished screw, substantial savings in material of the order of 15 to 20 per cent are obtained. Technically, screws produced by the thread hammering process are better because the material has a favourable grain flow undulating up and down the threads, which are metallurgically superior to cut threads (with their accompanying broken grain flow). Further, the material is work hardened in the hammering process, the screws produced by this method being 20 per cent stronger. A notable point is that there is no swarf. *Crossley Brothers Ltd.*, Openshaw, Manchester, 11.

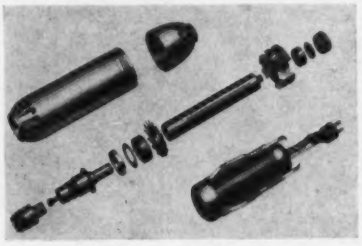
EMD 6493 for further information



High Frequency Motors

Demonstrated for the first time in the U.K. will be two special high-frequency motors and suitable rotary converters made by C. Oberg Machine Co., of Sweden. The motors, which are of two-pole three-phase squirrel cage construction, are made to a new design which enables the overall dimensions to be kept extremely small, e.g. motor No. 10 is 1·3 in. dia. × 5·3 in. overall, and motor No. 17 (illustrated) is 1·8 in. in dia. × 7 in. overall. These units run on 42-50 V., and have a speed range of 27,000 to 70,000 r.p.m., the rotary converters giving up to 1,200 c/s.

Also being exhibited is the Hakanssons Swedish metal cutting bandsaw (which has now become available in the U.K.), the Lark tube and surface descaling equipment, Lark pneumatic hand motors from 10,000 to 100,000 r.p.m., Oberg Swedish tungsten carbide and high-speed steel



burrs and engineers' files, and Compac and Parvus Swiss dial gauges and measuring equipment. *H. Williams & Son Ltd.*, Lark Works, St. Albans, Herts.

EMD 6494 for further information

Infinitely Variable Speed Unit

This company, which is the sole U.K. agency for the German manufacturers (Albrecht Mauser K.G.) of Ringspann units, will be including in their exhibits a new patented infinitely variable speed gear unit featuring backlash-free reversing with upwards of 92 per cent efficiency even on partial loading. Running temperature remains low also on maximum load, in spite of a design requiring less space to house the unit than is normal. Running is claimed to be unusually quiet, vibrationless and friction-free.

It was possible to dispense with the spring-loaded shoe which normally bears on the chain in this type of unit, as the Ringspann design automatically effects chain-tensioning to suit varying loads and ratios of speed. A working model is to be shown under power.

Ringspann freewheels showing a new development of the Spray principle, and a range of clutches, will be exhibited. Representative items from other continental manufacturers will also be displayed. *Henry Pels & Co. Ltd.*, 32-38 Osnaburgh Street, London, N.W.1.

EMD 6495 for further information

Metallic Bellows

Interesting current developments include the use of bellows for purposes other than straightforward expansion and contraction problems. A novel application for bellows units is in their use as sealing mechanisms for standpipes in a nuclear power station. In this application the bellows are used not only as pressure vessels

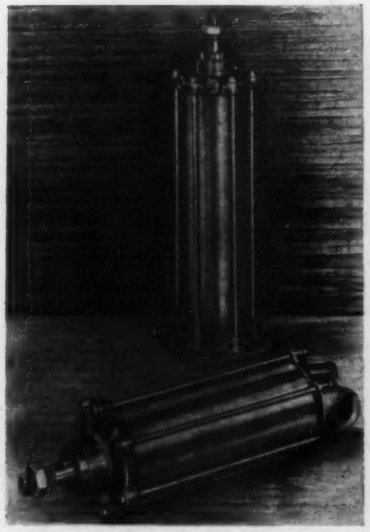
but also as springs, so that when the mating surfaces are placed together the spring characteristics of the bellows provide the necessary reaction forces to form the seals. *Munro & Miller Ltd.*, Sighthill, Edinburgh.

EMD 6496 for further information

New Air Cylinder

Introduced at the exhibition will be a new range of heavy-duty air cylinders in two sizes, 4½ in. and 6 in. bore, with various mounting arrangements and optional cushioning. A very high specification has been laid down for these new cylinders, which have exceptionally strong duralumin forged ends, stainless-steel piston rods and self-lubricating piston ends capable of exerting a thrust of 1 ton from an air line of 80 p.s.i. *Benton & Stone Ltd.*, Aston Brook Street, Birmingham, 6.

EMD 6497 for further information



EMD 6405 for further information

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WHAT'S NEW IN MATERIALS

Fireproof Partition

Polyroc is a lightweight fire-resisting partition or light bulkhead panel, with a phenolic foam core, which can be adapted to a variety of uses. It can be supplied with standard or fire-resisting grade Polypanol-H/F on one or both sides, in sizes up to 8 × 4 ft. Standard thicknesses are 1¼ and 1½ in., but other thicknesses are available to order. These panels will not spread flame, it is claimed, and the phenolic foam core does not melt or burn.

This product is a new development, and it is anticipated that when fire barrier tests have been completed a very satisfactory rating will be achieved. Polyroc panels are remarkably rigid for their weight and thickness, and are said to have very good thermal insulation characteristics. The thermal conductivity of the phenolic core is 0·27, and the "U" value of 1½-in. Polyroc is approximately 0·12. *Plastics Marketing Co. Ltd.*, Buckhurst Avenue, Sevenoaks, Kent.

EMD 6498 for further information

Mould Release Agent

Solvosil is a pure silicone aerosol that has the advantage of lasting for several mould castings. It is more durable and leaves a cleaner surface than French chalk, which was relied upon in the past. This point is of value to manufacturers in plastics and rubber. Since Solvosil is colourless, tasteless, non-toxic and chemically inert, it is also ideal for use in the packaging industry. In the food industry, it is suitable for the waxed papers used in packaging, since it will prevent sticking.

Confectionery manufacturers find that Solvosil facilitates the cutting of sweet papers; the anti-stick properties are also useful in the clothing and paper industries. In addition, Solvosil is used as a filament lubricant in the manufacture of artificial fibres, such as nylon and Terylene. *Solvolene Lubricants Ltd.*, Reginald Square, London, S.E.8.

EMD 6499 for further information

Flame and Moisture-resistant Fibreboard

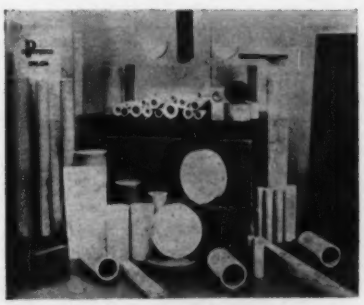
A new fibreboard, flame-proofed throughout and moisture-resistant, is called Pyrestos Dribord. It is pressure impregnated—not merely on the surface, but inside the board itself. This means that there is no risk of flame spreading unseen along the back of a lining, nor does cutting, rebating or grooving reduce the fire resistance. It is claimed to have exceptionally high resistance to moisture absorption, due to impregnation with a moisture-proofing agent in addition to Pyrolith, the fire-retardant preservative.

Pyrestos Dribord has not only achieved an official Class I rating for flame spread, but it does not support flame when subjected to the BS 476 spread of flame test; its density and sound absorption figures are of the same order as those associated with untreated fibre insulation board. It is available in standard sizes and thicknesses, and can also be supplied cut to special sizes, and bevelled, etc. It may be used in its natural state (it is pale fawn in colour), or painted, or alternatively it may be purchased white painted on one side. *Pyrestos Ltd.*, 8 Buckingham Palace Gardens, London, S.W.1.

EMD 6500 for further information

Nylon Tube

Over one hundred standard sizes of MC nylon tubes, ranging from 2 in. o.d. × 1 in. i.d. to 15 in. o.d. × 14½ in. i.d. are now available. MC nylon is a specially formulated polyamide which has been developed particularly for bearing and wear part applications, and which may be readily machined into components



such as bearings, bushings, guides, slideways, valve seats, gears and other wear parts from tubes, plate discs, square, round and hex. rod.

It is not generally realised that lubricated nylon bearings will operate under the same load and speed conditions as orthodox phosphor bronze bearings, and will often out-perform the latter material. Perhaps one of the most attractive features of MC nylon is the fact that, although it is only one-seventh the weight of an equivalent-sized bronze bearing, it is comparable in price. *Polypenco Ltd.*, 68-70 Tewin Road, Welwyn Garden City, Herts.

EMD 6501 for further information

Non-slip Roller Covering

Cling fabric consists of an inert, permanently non-slip, compound supported internally by woven fabric of high-tensile glass fibre. The overall thickness is 0·050 in. Covering a roller with the fabric increases the diameter by about $\frac{1}{32}$ in., and the circumference by about $\frac{1}{16}$ in.

The compound is formulated with non-migrating plasticisers, and is said to be highly resistant to oils, acids, alkalis and other chemical substances. It is claimed that it does not age, and that normal working temperatures up to 150 deg. F. will not cause deterioration. The surface can be cleaned by wiping with a cloth moistened with solvent such as trichloroethylene.

Cling has a Shore hardness of about 40, giving a clinging resilient surface which takes a firm grip of yarns, fabric (especially the slippery man-made fibres), paper, timber, steel sheets, wire and packages such as tin or plastics containers, cardboard cartons, etc. The supporting glass fibre fabric is specially designed for strength and non-stretch. The back of the fabric is coated so that the glass fibres are held firmly, thus preventing any distortion of the weave under strain. *Tannoid Ltd.*, Church Row Works, Wandsworth Plain, London, S.W.18.

EMD 6502 for further information

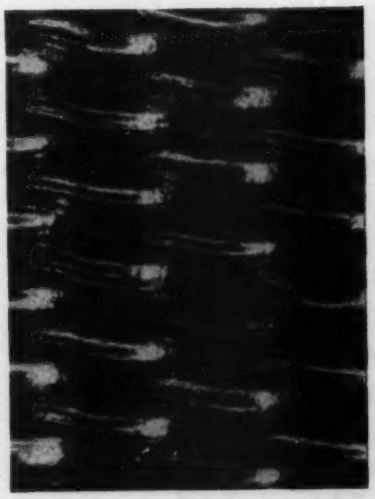
Mesh Wirecloth

A new superfine filter medium primarily developed for precision hydraulic and fuel systems in the aircraft and rocket industry is now being woven commercially for the first time in the U.K. Designated 325/2300 mesh Micro-Hollander stainless steel wirecloth, it is claimed to possess a high degree of uniformity and to retain particles of the order of 10 microns (0·00039 in.) as compared with 35·6 microns in 400/400 mesh.

The new Micro-Hollander is woven with 0·001 in. diam. wire, 1 sq. in. of cloth comprising 325 warp wires running lengthwise, interwoven with 2,300 tightly knocked up weft wires. Being twill woven, the individual wires in one direction pass alternately over two and under the next two cross wires in succession. This provides 747,500 openings per sq. in. (the illustrated mesh is magnified 225 times). Unlike square woven wirecloths, the openings in the Hollander specification are not apertures in the true sense of the word. Although absolutely uniform in critical dimension, they follow a sinuous path through the thickness of the cloth, and do not permit transmission of light; permeation of liquids is only possible under pressure.

The material offers many advantages over other filter media, not least being the accuracy and regularity of limiting opening size. Its robust structure permits high operating pressures, and since it is made of stainless steel, it has excellent corrosion-resisting properties and can be used over a wide temperature range. *The United Wire Works Ltd.*, Edinburgh.

EMD 6503 for further information



WHAT'S NEW IN COMPONENTS

Proximity Detector

The Airmec proximity detector (type N266) is a capacity-operated switch with a wide range of application in the fields of measurement and control. It is influenced by any physical variable appearing as a small movement, and its sensitivity is such that it is claimed to be able to detect a capacity change of 0·05 micro-farads, representing a movement of the order of tenths of thousandths of an inch under suitable conditions.

The equipment consists of a control unit housed in a robust light-alloy industrial case sealed against dust and moisture, together with a sensing probe. The probe may be mounted directly on the case or at the end of a flexible armoured cable, which may be up to 30 ft. in length without loss in sensitivity. The probe, which contains no electronic components and is therefore unaffected by heat or rough treatment, may be fitted with a cover for use in liquids or corrosive atmospheres. A transistorised printed circuit is employed for its high reliability, and either a mains power unit or a battery unit is fitted to order. Under maximum current conditions the battery life is in excess of 200 hr., at 4 hr. a day, but in many applications the battery life is said to exceed the shelf life.

A high stability is claimed for the equipment; mains voltage variations over the range 180-260 V., and temperature changes of 20 deg. C. can be tolerated without significant change of operating point. In addition to well-known applications such as level control and counting, the unit may be used for sorting, grading, gauging, limit switching and any process involving the detection of small variations in the position or nature of both conductors and insulators. *Airmec Ltd.*, High Wycombe, Bucks.

EMD 6504 for further information

Over-heat Detector

Installed on many modern military aircraft to warn crews of impending danger, Kidde's overheat-fire detector is now also used to protect industrial equipment. The detector consists of a closed loop of sensitive element, sometimes 100 ft. long, with a negative temperature coefficient of resistivity—its resistance drops with a rise in temperature. One or more of these elements placed near the surface of vital equipment continuously monitors for overheat conditions.

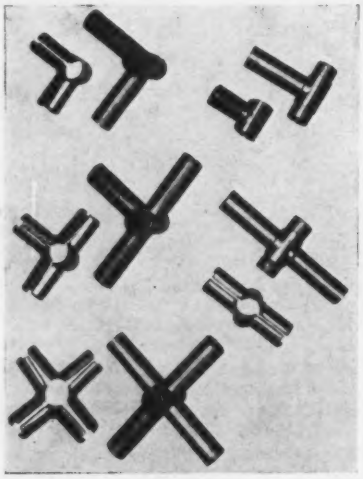
Danger warnings go to plant personnel through a control box coupled to an audio or visual alarm. The detector's outstanding feature is that it monitors the temperature every inch of the way, not just in parts like other temperature-sensing devices. Series connection of several sensing elements of varying coefficients of resistivity permits coverage of multi-temperature hazards.

The sensing element is claimed to be impervious to oil, dirt and solvents. If damaged or broken, it still continues to monitor, except at the point of rupture. Even if more than one break occurs, the system functions at all points except between the breaks. After giving warning, the detector re-sets automatically when the hazard is eliminated. *The Walter Kidde Co. Ltd.*, Northolt, Middlesex.

EMD 6505 for further information

New Tubular Construction System

For the rapid erection of tubular structures such as racks, benches, shelves, etc., a new system of construction known as



Clinch is announced. The joints operate on the principle of internal pressure of one tube balancing the external pressure of the other. The single T joint, for example, is slid over the first tube, and the sprung spigot stems are then compressed with a self-locking wrench or spanner and inserted into the right-angle tube. The joint is then driven home with a hammer or mallet.

A particular advantage of the system is that the joint produced is neat and clean, and only a hacksaw and the above tools are necessary. Clinch joints, some of which are shown, are available for 1¼ in. o.d. × 16 s.w.g. resistance welded tube. Joints for 1 in. o.d. tube will be available shortly. Castors and roof and floor pads employing the same split tube insertion principle are also available for making racks and trolleys. *Access Equipment Ltd.*, Maylands Avenue, Hemel Hempstead, Herts.

EMD 6506 for further information

Non-return Valve in Plastics Materials

The most recent addition to the Barflo range of all-plastic valves is a non-return unit. This "flap-type" can be constructed

from most rigid plastics, the "flapper" being made from neoprene rubber. Other designs are available, and most operating conditions can be met. The valve can be made in most plastics tube sizes for vertical and horizontal operating. *Barflo Ltd.*, 56 Cavendish Place, Eastbourne.

EMD 6507 for further information

Motors with Encapsulated Windings

An improved type of protection for the windings of electric motors by epoxy resin encapsulation has been announced. The stator windings are impregnated and covered completely with the resin. The process is claimed to render the motors completely impervious to attack by moisture, oil and most chemicals, and to provide protection from mechanical damage caused by the abrasive action of airborne solids. The epoxy resin encapsulation is being offered for all types of Newman motors, both open and closed, ranging from 1 to 125 h.p.

It is stated that encapsulated drip-proof motors can often replace totally enclosed motors in applications where resistance to chemical fumes and moisture is needed. They can not be used, however, for situations where solid particles are liable to clog the air gap between the stator and the rotor. *Newman Industries Ltd.*, Yate, Bristol.

EMD 6508 for further information

Viscosity Meter

The Rheomat 15 viscosity meter made by Contraves A.G., of Zürich, is designed for the quick and reliable determination of the flow conduct of liquids and pastes. The substance to be tested is placed in a measuring beaker, the bulb of the meter is immersed in the fluid, and the results read off. The viscosity meter consists of the control unit and the Rheometer proper. Speeds are adjusted by turning a sixteen-step switch, which is installed in the frequency transmitter proper.

When switching to 1, a magnetic relay in the Rheometer engages the smallest gear ratio, and the 30-pole synchronous motor is fed with the lowest frequency (28·8 c/s); the bulb then rotates at the rate of 5·59 r.p.m. At position 6, medium speed is cut in, and at position 11 the highest gear ratio goes into effect. The "Rheogram" is recorded after the pointer deflections registered at each step, thus establishing a graph of the flow conduct of the substance being tested. *Short & Mason Ltd.*, Aneroid Works, 280 Wood Street, Walthamstow, London, E.17.

EMD 6509 for further information

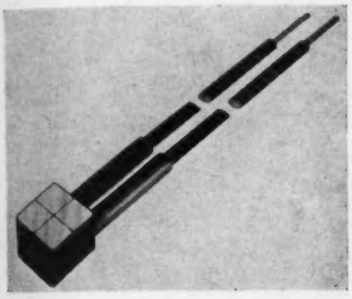
FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

WHAT'S NEW IN COMPONENTS

Thermoelectric Cooling Unit

The first of a range of thermoelectric cooling units has been announced. Based on the Peltier effect, whereby heat is generated or absorbed at the junction of two dissimilar materials when a direct current is passed across the junction, the cooling capacities vary from less than 1 W. for a single-junction type to more than 10 W. for a single-junction type to more than 10 W. for a large multiple junction.



They thus cover a range which cannot be conveniently dealt with by conventional means of refrigeration.

The first of the group to be readily available is the BT.4, a four-junction unit with a cooling capacity rated nominally at 1 W., although the rating can be increased with a resultant reduction in temperature depression. Alternatively, a greater temperature depression can be achieved by reducing the rating.

The BT.4 is made in the shape of a small cube, and thermal junctions are formed by a combination of p and n types of a bismuth telluride semi-conductor material. In use, the block is clamped between the object to be cooled and a heat sink. Typical of its many applications is the cooling of electronic components which must operate in high ambient temperatures, when it serves to increase the power ratings of transistors, reduce the dark current in photo-transistors or, in the case of quartz crystals, to allow operation at the inversion point or other selected part of the frequency deviation/temperature characteristic.

Other applications are with laboratory equipment such as microtome knives or microscopic slides, where local cooling is essential; with instruments such as dew-point hygrometer heads, where thermoelectric cooling involves changes in techniques and resultant simplification in the equipment; and with the cooling of small volumes by incorporating one or more units into the walls of a chamber. Here, the temperature may be held constant by a proportional controller which allows smooth regulation of the cooling rate via the d.c. current applied. *Salford Electrical Instruments Ltd.*, Magnet House, Kingsway, London, W.C.2.

EMD 6510 for further information

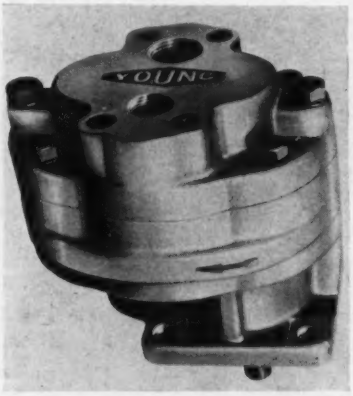
Oil Hydraulic Gear Pumps

A new range of hydraulic gear pumps of advanced design has been developed. These units are of the constant displacement type, and are primarily intended for heavy-duty applications involving either continuous or intermittent operation such as mechanical handling equipment, coal mining appliances, earth moving vehicles and hydraulic control systems of all kinds. There are four basic models in the new range, each being available with side or end ports. The respective capacities are 12·5, 18, 24 and 30 gal/min. at 1,000 r.p.m. All have square flange mountings and are interchangeable.

An important new feature is that the direction of rotation can be changed simply by inverting the end plate. Another new development is a system of grooves formed in the end cover which relieves the build-up of pressure due to the trapping of oil at the bottom of the gear teeth, and eliminates pressure on the oil seals and joint faces.

The new design of the four cheek plates is claimed to ensure continuous maximum working pressure. They are "relieved" for balancing the gears laterally, thereby avoiding an uneven pressure loading on the gear faces. Also new is the positioning of the driving shaft by deep groove ball bearings, so that no side thrust is imposed on the gear faces or cheek plates. Radial load of both shafts is taken by rigid needle roller bearings.

The gears are machined from high-duty alloy steel, case-hardened and ground to fine limits, and have special deep-formed large-capacity teeth. Pump bodies are



available in high-duty aluminium alloy or close-grained cast iron. *Joseph Young & Sons Ltd.*, Kay Street, Bolton, Lancs.

EMD 6511 for further information

Servo-system Analysis

A radically new approach to the problems associated with the design of servo-control systems has resulted in the development of a range of instruments which will greatly speed and simplify all design procedures which involve the use of transfer functions.

The first instrument in this range to become available is the transfer function computer, SA100. It is a self-contained instrument operating over the frequency range 0·1 to 500 c/s, or, alternatively, with repetitive impulse functions, square-wave or triangular-wave outputs. The response of the system being analysed is fed back to the computer.

Operation is said to be extremely simple. The computer provides directly the values of the coefficients belonging to the differential equation to the system. Thus the transfer function is immediately known, and from this the roots of the denominator can be extracted. Hence, the complete behaviour of the system is related directly to its physical parameters.

When adjustments have been made to a control system, the revised values of the coefficients can be obtained from the computer, even by unskilled operators, in a matter of minutes. In contrast, existing phase and amplitude measurement procedures, with the associated graphical analysis, frequently require many hours, or days, of highly specialised calculation. *Wayne Kerr Laboratories Ltd.*, 44 Coombe Road, New Malden, Surrey.

EMD 6512 for further information

Flow Indicator for Opaque Liquids

The Magnetel flow indicator is designed to observe the flow of an opaque liquid through a pipeline. It can be used with liquids of almost any viscosity, such as thick oils, and is equally suitable for indicating flow either horizontally or vertically upwards.

As the fluid travels through the chamber of the indicator, it moves a hinged metal flap which incorporates a set-in magnet to operate a pointer against a scale. As there are no springs or other moving parts, the risk of mechanical breakdown or jamming is eliminated, and the pointer and scale are in a separate chamber so that the fluid cannot obscure the window. A particular feature is that the Magnetel can be easily adapted for extremely low flow rates, even the smallest change in relative flow being shown against the scale.

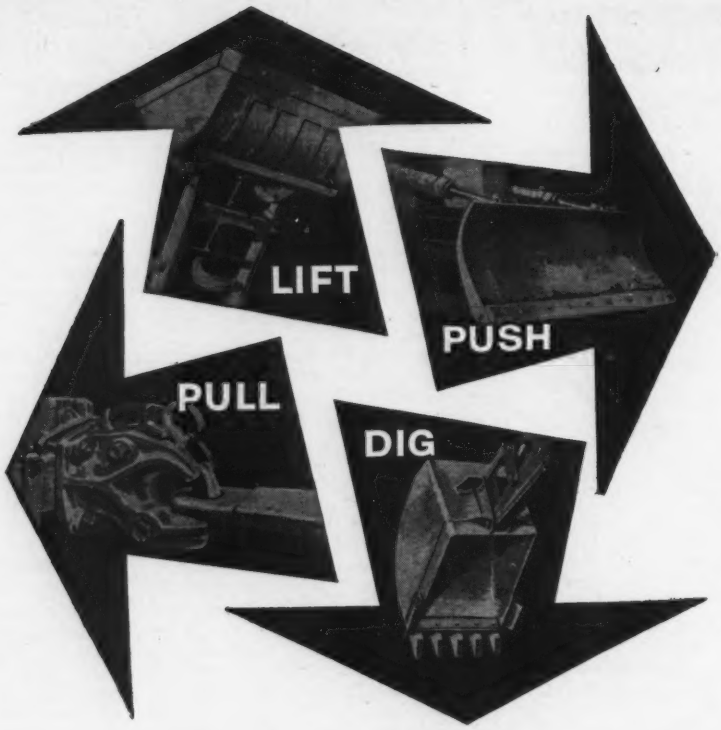
In situations where the liquid may contain ferrous particles which might adhere to the magnet, a special screened unit is available in which the magnet is fully enclosed in an intermediate chamber. A switch unit is also available, in which when flow stops completely or falls below a certain rate, a switch is automatically operated to give an audible indication of the emergency.

The Magnetel is available in standard ½-, ¾-, 1- and 1½-in. sizes, with ends screwed B.S.P.T., and adapters to match ¾ and 1¼ in. The 2-in. size has flanged ends. *Sir W. H. Bailey & Co. Ltd.*, Albion Works, Patricroft, Manchester.

EMD 6513 for further information

Please Note!

We receive many reader enquiry cards on which the reader has omitted to fill in his name and address. In order to avoid disappointment we remind readers that names and addresses should be included on *each* card.



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B.H.P.	52 @ 1600	32 @ 2000
Torque lbs/ft (nett)	162 @ 1200	92 @ 1200
GEAR RATIOS (6 speed constant mesh)		
1st Gear	6.62 : 1	30.5 : 1
2nd Gear	4.70 : 1	17.0 : 1
3rd Gear	3.68 : 1	10.28 : 1
4th Gear	2.61 : 1	7.55 : 1
5th Gear	1.87 : 1	5.73 : 1
6th Gear	1.04 : 1	2.53 : 1
Low Rev	4.90 : 1	6.30 : 1
High Rev	2.73 : 1	18.70 : 1
REAR AXLE RATIOS		
Crownwheel and Pinion	3.5 : 1	6.66 : 1
Spur Gear Reduction	5.308 : 1	—
Overall Reduction	18.58 : 1	—

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WHAT'S NEW IN THE OFFICE

Planning Board

The Vidento planning board has sixty-two indicating columns into which fall tiny precision balls, giving the impression of columns of mercury. Sixteen thousand balls are kept in a "reservoir" at the top of the board, and columns are filled by depressing the numbered buttons. A column can be reduced by depressing the parallel buttons at the bottom of the board, thus allowing the required balls to fall into a removable receiving container. The mechanism of the buttons is such that only one ball can enter or leave a column when the respective button is depressed. However, a master button can be used if a column has to be rapidly filled or emptied.

To identify the column there is a visible index consisting of sixty-two windows at the bottom of the board. Vidento has a vertical scale, from zero to 220, which is clearly divided into units of five. The front of the board is covered by a pane of plexiglass, which can be written on with the special colour crayons supplied with the equipment. One of the great advantages of Vidento is that it can be locked completely. *Archimedes Diehl Machine Co. Ltd.*, Chandos House, Buckingham Gate, London, S.W.1.

EMD 6514 for further information

Improved Sensitised Material

Ammo industrial foil has been in use in a number of drawing offices for many years. Its main attribute as an intermediate is to increase the density of a final print by an intensification of the line when the original is a pencil drawing. This attribute is now available in Ammo Permatrace with the added advantage of stability. Stable reproduction on an almost indestructible material is now possible.

Pencil drawings prepared on tracing paper or preferably on Permatrace can now be reproduced on Ammo Permatrace, giving a permanent record with high quality line definition and good contrast. Modification to the translucent intermediate can be readily made by removing the line with a correcting fluid or green eraser, leaving a matt surface on which corrections can be made.

Undoubtedly the main use for this new product will be in the production of translucent intermediates for general works' use, sub-contractors and line intensification of existing drawings. But Ammo Permatrace will also be of value in many industries where reproductions are required with accuracy and dimensional stability. *Lawes Rabjohns Ltd.*, Abbey House, Victoria Street, Westminster, London, S.W.1.

EMD 6515 for further information

Copy-Scanner

The Copy-Scanner is a visual aid which will enlarge or reduce an original subject to any required size. From the enlargement or reduction, drawings and tracings can be obtained, since the image is clearly defined. The original can be an illustration or even an actual object, and the image can be viewed on a comfortably-angled screen.

The light source is cold, thereby eliminating possible damage to originals or cockling, where photoprints are used. There are powerful additional floodlamps, and the open copy board incorporates extension rods and magnetic clips to keep the original flat and distortion free. A special gearing system ensures fine focusing by controlling, in slow motion, movement of both lens and copy platforms to give accuracy of size and image definition. Apart from the high-definition lens, a supplementary lens is provided giving enlargements up to 4:1. The unit is easily and quickly converted from horizontal to vertical plane.

The size of the copy board is 22 in. by 21 in., with extension arms to 48 in. by 36 in., and the screen size is 22 in. by 16½ in. The Copy-Scanner takes up an operative floor space of only 24 in. by 21 in., and its height at drawing-board angle is 42-50 in. Castors on the front feet of the unit give portability, and rubber-covered feet at the rear ensure stability. *Colyer & Southey Ltd.*, 17-18 Tooks Court, Cursitor Street, London, E.C.4.

EMD 6516 for further information

New Publications and Technical Literature

Electronic Instruments Ltd.: "pH Meters by E.I.L.", a 12-page illustrated catalogue describing the company's range of pH meters. Richmond, Surrey.

EMD 6517

Laporte Chemicals Ltd.: 80-page manual of physical and chemical data on hydrogen peroxide, including information on handling and storage. Luton, Beds.

EMD 6518

Johnson, Matthey & Co. Ltd.: 30-page booklet of data on the firm's range of electrical contacts. 73-83 Hatton Garden, London, E.C.1.

EMD 6519

Billetop & Gilpin Ltd.: Leaflet giving the dimensions and tolerances of Holfos Bronze standard bearing bushes. Syston, Nr. Leicester.

EMD 6520

John Harper & Co. Ltd.: Leaflet of data on the company's cast-to-form tools. Albion Works, Willenhall, Staffs.

EMD 6521

Stuart Davis Ltd.: Well-produced 39-page catalogue of Red Ring pneumatic cylinders and valves. Stonebridge Highway, Willenhall, Coventry.

EMD 6522

Spicers Ltd.: Brochure describing Netlon, which is a thermoplastic mesh integrally extruded in tubular form. 19 New Bridge Street, London, E.C.4.

EMD 6523

Hadfields Ltd.: "Fine Steels", a 36-page brochure of data on alloy steel billets, bars, slabs and forgings. East Hecla Works, Sheffield, 9.

EMD 6524

Holo-Krome Ltd.: 17-page catalogue of data on the firm's socket screw products. Griffin House, Ludgate Hill, Birmingham, 3.

EMD 6525

A. A. Jones & Shipman Ltd: 11-page booklet describing the company's range of precision machine tools. 50-52 Great Peter Street, London, S.W.1.

EMD 6526

Head, Wrightson & Co. Ltd.: 15-page illustrated brochure concerned with electrostatic precipitation plant, comparing this method of gas cleaning with other systems and covering briefly the application of this equipment in the iron and steel industry. Ship House, 20 Buckingham Gate, London, S.W.1.

EMD 6527

Lodge Plugs Ltd.: 36-page brochure of technical information and data on Sintox, a high-alumina ceramic material manufactured by this company. An abbreviated 8-page version is also available. Rugby.

EMD 6528

British Gear Manufacturers Association: Buyers' guide available to bona fide manufacturers and users of gears, containing a list of the member companies (and details of their products), and also a classified list of gears. 301 Glossop Road, Sheffield 10.

EMD 6529

London Shafting & Pulley Co. Ltd.: Three leaflets of technical data on the firm's products — "Pin-type Flexible Couplings"; Com-Pac Wedge V Belt Drives"; and "Disc Flexible Couplings". Collingwood Iron Works, 18-22 Northdown Street, King's Cross, London, N.W.1.

EMD 6530

British Resin Products Ltd.: *Cellobond Polyester Resins*, a 230-page well-produced book available to those seriously interested in this subject. Devonshire House, Piccadilly, London, W.1.

EMD 6531

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News of Industry

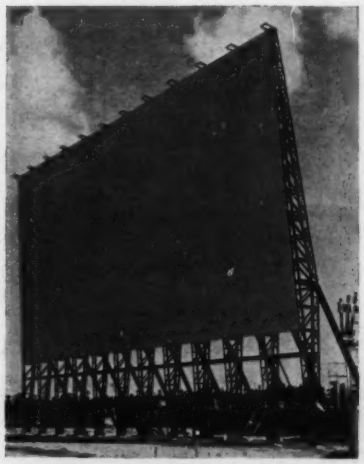
The electrical plant associated with a new cold rolling strip mill installed at **Steel, Peech & Tozer** embodies many of the latest developments and techniques in control. The motors are supplied from rectifier/inverter units which serve the dual function of powering the mill motors during rolling, and returning power to the supply during deceleration of the mill. Primary production is carried out on a four-stand, four-high tandem mill, and the new plant represents the most advanced design of tandem mill of this size, Nos. 1 and 4 stands being equipped with automatic gauge control, and automatic inter-stand tension control between Nos. 3 and 4 stands. During the rolling operation the strip is not in contact with guides of any description, and maintains its central position in the mill by means of the interstand tension, which is infinitely variable. The equipment has been designed to cover a gauge range of 0·010 in. to 0·160 in. in widths up to 18 in., and although able to deal with all qualities of steel, the mill will be primarily employed on the cold rolling of low carbon steels in all tempers from hard bright unannealed to dead soft, and intermediate tempers in the annealed condition. Variation in surface finish will also be possible, ranging from matt to bright. Thus the designer will have a greater range of materials available than hitherto, and designs can be based more readily on functional requirements.

Tube Investments Ltd. announces an agreement with **Techne (Cambridge) Ltd.** for rights to manufacture a micro-tensile testing machine developed by the Tube Investments Research Laboratories, near Cambridge.

The machine deals with single crystal "whiskers" often too small to resolve with the naked eye. It employs a torsion balance to apply loads of 1 mg. to 400 gm. to specimens with cross-sectional areas as small as one 5,000 millionth of a square inch, and it measures, by optical and mechanical means, extensions in the specimen from a few Ångström units to 15 mm. It can readily be adapted for tests in compression, tests in special atmospheres, and for thin film testing.

Due to the successful application of Protexulate, a product of **Croxton & Garry Ltd.**, it has been found necessary to form a separate subsidiary company which is to be called **Protexulate Ltd.** Protexulate is a fine mineral powder, prepared by a patented process, for use in underground pipe installations, and provides buried heating pipes with a highly efficient thermal insulation with complete protection from corrosion. Protexulate, which is permanently waterproof and can be used for conduits with temperatures up to 250 deg. C., is poured direct from the bags into the trench, covering the pipeline to a depth based on the dimensions of the pipes. The empty multi-ply paper bags are then placed over the powder and the trench filled in with earth.

Sanders & Forster Ltd. have recently exported an unusual steel structure for supporting the cinema screen of Trinidad's third "drive-in" cinema to be opened in the near future at Point Fortin. Set at an angle of seven degrees to the vertical, the structure consists of twelve ribs, each 74 ft. high with horizontal steel channel members stretching across the full width to support the flat asbestos sheet screen which measures 110 ft. wide by 54 ft. deep. The ribs were designed as vertical cantilevers, each rib member being made in three convenient sections. The sides of these sections were fully prefabricated, leaving only the front and back lacing members to be site bolted to form the complete box. The complete structure was designed to withstand a wind of 85 m.p.h.



The formation of an Institute of Corrosion and the classification of workers in the corrosion field into research workers, specialists and general practitioners, on the lines of the medical profession, were two suggestions made at a recent meeting of the **British Association of Corrosion Engineers.** Developing the medical profession analogy, the speaker said that corrosion was a disease of industry, and should be attacked as the medical profession attacks disease. The corrosion engineer was the G.P. of the profession and to find the answer to many problems he must have the backing of specialists and research workers. Corrosion engineers should be called in to assist designers right from the initial stages and not when the structure was in danger of falling down.

MEETINGS AND EXHIBITIONS

The annual general meeting of **The Iron and Steel Institute** is to be held in London on May 3 and 4, 1961. There will be technical sessions devoted to the use of computers in the iron and steel industry, and to the Brymbo oxygen steelmaking process. At the same time, a joint symposium will be held with **The Institute of Metals** on structural processes in creep.

A one-day symposium on foamed rubbber and plastics is being arranged by the London Section of the **Institution of the Rubber Industry** and the **Plastics Institute**. This will be held at the Institution of Electrical Engineers, London, on Friday, May 5, 1961.

The Joint Symposium on Welding in Shipbuilding will be held in London in October/November 1961 and will be sponsored by the **Institute of Welding**, the **Royal Institution of Naval Architects**, the **North East Coast Institution of Engineers and Shipbuilders** and the **Institution of Engineers and Shipbuilders in Scotland**.

A one-year post-graduate course in welding technology will open in the autumn of this year at the **College of Aeronautics.** The purpose of the course, which has been sponsored by the **Institute of Welding and the British Welding Research Association**, is to provide students of graduate status, in either metallurgy or engineering, with a specialised training to fit them for posts in the design, development and production departments of the many industries where welding is now vital. Further details may be obtained from the Warden, the College of Aeronautics, Cranfield, Bletchley, Bucks.

FILMS

Hard Metal (second edition), presented by **Murex Ltd.**, shows in detail the manufacturing process, from the treatment of wolfram and scheelite ores to the production of tungsten carbide tips, tools and dies. The total running time of the film is approximately 50 min., and is available either for screening by Murex technical staff in customers' works or on loan, without charge, to technical colleges and other interested organisations. Apply to Central House, Upper Woburn Place, London, W.C.1, or any Regional Office.

A film, entitled *Your Eyes are Precious*, is a 16 mm. sound and colour film running for approximately 8 min. and deals particularly with situations which may arise in steel foundries. Its general theme of eye protection, however, is one which can be applied to any industry. Copies are available on loan from the **British Steel Founders' Association**, Broomgrove Lodge, 13 Broomgrove Road, Sheffield, 10.

The film *Satisfied Users*, produced by **International Computers & Tabulators Ltd.**, is concerned with the experience of a few of the many users of the I.C.T. 1200 series of computers, and some of the types of application in which these computers are giving service. The running time of the 16 mm. Ektachrome sound film is approx. 30 min. and is available on free loan from Films & Lecturing Dept., I.C.T., 149 Park Lane, London, W.1.

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